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RESEARCH ON RECYCLING OF WASTE LEATHER PRODUCED IN LEATHER MANUFACTURING PROCESS BASED ON SUPPLY CHAIN MANAGEMENT

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RESEARCH ON RECYCLING OF WASTE LEATHER PRODUCED IN LEATHER MANUFACTURING PROCESS BASED ON SUPPLY CHAIN MANAGEMENT

ABSTRACT. Leather industry is a consumer-goods sector closely linked with national economic development. With the slowdown of China's economic growth, the leather industry has entered a new normal of steady development under immense pressure. On the upside, the industry can enrich the material life of consumers. On the downside, leather production unleashes a series of threats to the environment. For example, it is urgent to recycle the gigantic amount of waste leather in such an environmentally conscious era. Therefore, this paper presents a model for the manufacturer who produces lots of waste leather in manufacturing, builds another model for the recycler who recovers the waste leather produced by the manufacturer, and combines the two models into an integrated model for recycling of waste leather produced in leather manufacturing process. Then, the model was applied to a numerical analysis.
KEY WORDS: waste leather, leather manufacturing process, supply chain management

CERCETĂRI PRIVIND RECICLAREA DEŞEURILOR DE PIELE GENERATE ÎN PROCESUL DE FABRICARE A PIELII PE BAZA GESTIONĂRII LANŢULUI DE APROVIZIONARE

REZUMAT. Industria de pielărie este un sector al bunurilor de consum, strâns legat de dezvoltarea economică naţională. Odată cu încetinirea creşterii economice a Chinei, industria de pielărie a intrat într-un nou ritm normal de dezvoltare constantă sub o presiune imensă. Avantajul este că industria poate îmbunătăţi viaţa materială a consumatorilor. Dezavantajul este că producţia de piele declanşează o serie de ameninţări pentru mediul înconjurător. De exemplu, reciclarea cantităţii uriaşe de deşeuri de piele este urgentă într-o perioadă în care omenirea este atât de conştientă de mediul înconjurător. Prin urmare, în această lucrare se prezintă un model pentru producătorul care generează o cantitate mare de deşeuri de piele, un alt model pentru reciclatorul care recuperează deşeurile de piele generate de producător şi se combină cele două modele într-un model integrat pentru reciclarea deşeurilor de piele generate în procesul de fabricare a pieilor. Modelul este apoi supus unei analize numerice.
CUVINTE CHEIE: deşeuri de piele, procesul de fabricare a pielii, gestionarea lanţului de aprovizionare

RECHERCHE SUR LE RECYCLAGE DES DÉCHETS DE CUIR GÉNÉRÉS DANS LE PROCESSUS DE FABRICATION DU CUIR À PARTIR DE LA GESTION DE LA CHAÎNE D'APPROVISIONNEMENT

RÉSUMÉ. L'industrie du cuir est un secteur de biens de consommation, étroitement lié au développement économique national. Avec le ralentissement économique de la Chine, l'industrie du cuir est entrée dans une nouveau rythme normal du développement stable sous une pression énorme. L'avantage est que l'industrie peut améliorer la vie matérielle des consommateurs. L'inconvénient est que la production de cuir déclenche un certain nombre de menaces pour l'environnement. Par exemple, le recyclage de la quantité énorme de déchets de cuir est urgente à un moment où l'humanité est si consciente de l'environnement. Par conséquent, cet article présente un modèle pour le producteur qui génère beaucoup de déchets de cuir, un autre modèle pour le recycleur qui récupère les déchets de cuir générés par le fabricant et combine les deux modèles dans un modèle intégré pour le recyclage des déchets de cuir générés dans le processus de fabrication du cuir. Le modèle est ensuite soumis à une analyse numérique.
MOTS CLÉS: déchets de cuir, processus de fabrication du cuir, gestion de la chaîne d'approvisionnement

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INTRODUCTION

Leather is a popular consumer good with excellent flexibility, permeability and heat resistance. The production of the durable material requires a series of meticulous procedures [1-2].

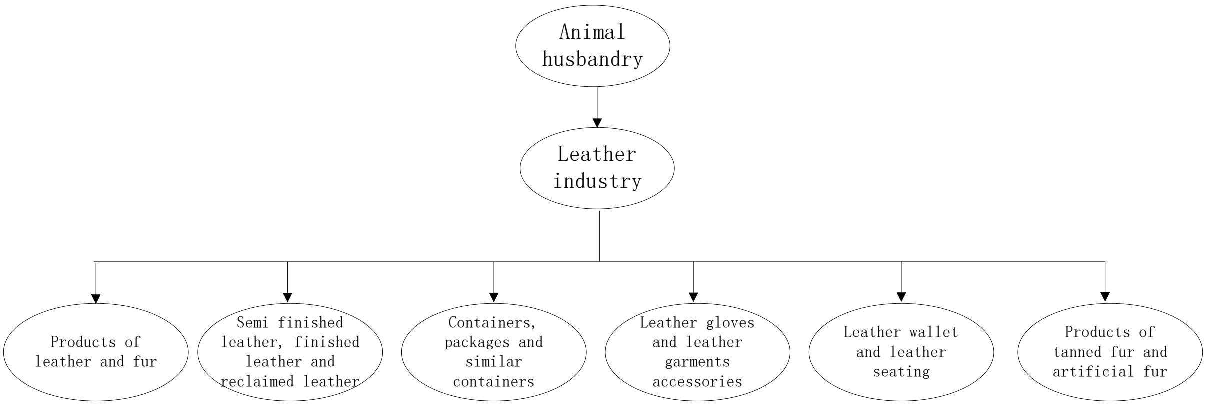

Figure 1. Sketch map of leather industry chain

Since the last century, China has developed into a leading producer of leather products [3-4]. The remarkable achievement is inseparable from the complete industry chain and low labour cost in the country. In recent years, however, the development of China's leather industry has slowed down to single-digit growth, and even negative growth. To reverse the trend and revive its leather industry, China should deepen its structural reform, encourage individual innovation, and promote waste leather recycling [5].

The existing studies mainly discuss the recycling of waste leather in the consumer market [6-7], but rarely tackle the production of waste leather in the leather manufacturing process. The leather waste both possesses pollution potential and economic value. In light of the above, this paper probes into the recycling of waste leather produced in leather manufacturing process. First, an integrated model was established in which the manufacturer produces waste leather and the recycler recovers the produced waste leather; then, the model was improved based on supply chain management, aiming to maximize the overall profit.

Development of Leather Industry in China

The leather industry is a pillar of light industry in China. Recent years have seen the rapid development of China's leather industry, turning the country into a major producer and a promising market of leather [8]. Through structural optimization, many specialized producing areas and consumer markets of leather have formed in China, laying the basis for further development of the industry [9].

Currently, the leather industry contributes a large share (>7%) to China's GDP and directly bears on the national economy. In return, the industry growth is heavily influenced by the overall economic situation. With RMB appreciation and slowdown of global economy, the growth of domestic demand becomes the most important driving force to the leather industry [10].

According to the National Bureau of Statistics of China, the main business income and total profit of leather, fur, feather and related products and footwear manufacturing industry from 2013 to 2016 are shown below.

The growth rates of main business income and total profit are presented in the figure below.

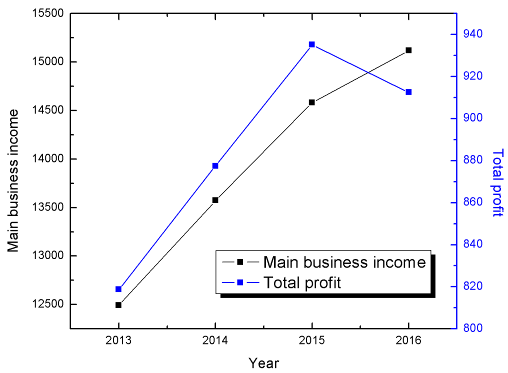

Figure 2. Main business income and total profit

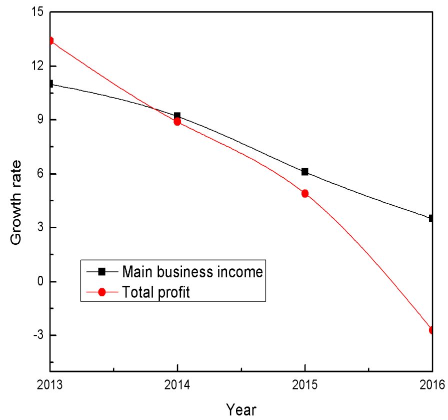

Figure 3. The main business income and its total profit growth rate

As can be seen from the figure, the main business income and total profit of leather, fur, feather and related products and footwear manufacturing industry in China has been growing at a decreasing rate. In 2016, the total profit growth even entered negative territory.

Specifically, the growth rate of the main business income dropped from 11% in 2013 to 3.5% in 2016, while that of the total profit declined from 13.4% in 2013 to -2.7% in 2016.

Table 1: Development of leather industry in China

Years	Main business income	Growth rate	Total profit	Growth rate
2013	12493.1	11	818.7	13.4
2014	13572.9	9.2	877.5	8.9
2015	14580.8	6.1	935.2	4.9
2016	15118.8	3.5	912.5	-2.7

The continued decline is attributable to the lack of innovation, poor brand power, surging cost, and weak demand. In particular, the growth rate of the total profit turned negative in June 2016, the first ever negative growth since 1998. Facing the seemingly irreversible downward trend and the pressing need for industry upgrade, China must deepen the supply-side reform, optimize the supply structure, expand domestic demand, encourage technological innovation, promote product upgrading, implement production adjustment, accelerate market transformation, and pursue sustained healthy development.

Recycling of Waste Leather Produced in Manufacturing Process

It is inevitable that a great deal of waste leather will be produced in the manufacturing process of leather products. The waste leather is mainly disposed via landfilling, incineration and chemical treatment. Nevertheless, none of these methods are sufficiently effective. For instance, the incineration of waste leather may produce toxic gases like nitrogen oxides and sulphur oxides. The improper disposal of waste leather poses a great threat to the environment and our health [11].

The leather products are often processed by chrome tanning. The chrome tanned products are hard to decay, well ventilated and resistant to moisture. The question is chromium, as a toxic heavy metal, can easily access human cells, causing damage to the liver, kidneys and other internal organs. The accumulation of chromium in the body may induce cancer and genetic mutations. If not properly treated, the waste leather will also have a negative impact on the environment [12-13].

Figure 3. Piles of waste leather

If the waste leather produced in the leather manufacturing process is properly recycled, there will be immeasurable economic and social benefits. For one thing, proper recycling can fully unlock the recovery value of waste leather, save a wealth of energy, and indirectly promote economic growth. For the other thing, the proper recycling helps to implement the national strategy of sustainable development. As Chinese President Xi Jinping puts it, "Lucid waters and lush mountains are invaluable assets" [14-15].

In general, the following are the meanings to recycle the waste leather produced in leather manufacturing process:

1. Environmental protection: The recycling can eliminate the polluting polymer materials in waste leather, creating a good living environment to mankind. Whereas the production of leather, be it natural or artificial, must consume environmental resources, the recycling of waste leather is bound to alleviate the waste of resources.

2. Economic interests: With the depletion of social and renewable resources, manufacturers are facing increasing pressure on resource acquisition. Many are forced to control resource consumption and make full use of the existing materials. If the massive amount of waste leather is recycled, there will be much less resource consumption and huge economic benefits.

3. Social benefits: Known for its environmental-friendliness, the recycling of the waste leather will definitely promote the brand image, the key to the existence and development of manufacturers. To protect the good image, manufacturers will devote much of their energies to promoting social benefits.

METHOD - MODEL ANALYSIS

This section investigates the recycling of waste leather produced in leather manufacturing process. Both the manufacturer and recycler of leather belong to a supply chain, which covers the entire process from product design, raw material procurement, product fabrication, packaging, to delivery [16-17].

Manufacturer Model

In the daily production of leather products, the manufacturer produces a large amount of waste leather. The production of the waste leather is both a waste of resources and threat to the environment. It is assumed that the manufacturer produces lots of waste leather, and that the waste leather is recycled by a professional third party recycler at the government-guided price.

The relationship between the output and the price can be expressed as:

$$P_x = \alpha - \beta Q_x (\alpha, \beta > 0) \quad (1)$$

where Px is the price of the waste leather sold to the downstream company; Qx is the output of the manufacturer; α is the minimum price when the downstream company does not have the demand; β is the price sensitivity of the output, i.e. the price reduction at each unit of increase in the output. It can be seen from formula (1) that the output is linearly correlated with the price.

Then, the unit production cost, the unit inventory cost and the unit labour cost are denoted as C_m, η_1 and μ_1, respectively. Suppose that the recycler must compensate the manufacturer in the process of recycling.

In the course of recycling, the amount of recycling Q_c depends on the rate of return P_w in the dynamic recycling market. The relationship between the two parameters can be expressed by a resource supply function:

$$Q_c = w + \varphi P_w (w, \varphi > 0) \quad (2)$$

where w is the recycling amount at zero rate of return; ɸ is the sensitivity of the recycling amount to the rate of return, i.e. the recycling amount increment at each unit of increase in the rate of return.

The manufacturer's profit is:

$$\pi = (P_x - C_m - \eta_1 - \mu_1)Q_x + Q_c P_w \quad (3)$$

Under the Nash equilibrium

$$\frac{\partial \pi}{\partial Q_x} = \alpha - 2\beta Q_x - C_m - \eta_1 - \mu_1 \quad (4)$$

if

$$\frac{\partial \pi}{\partial Q_x} = 0 \quad (5)$$

we can get

$$Q_x^* = \frac{\alpha - C_m - \eta_1 - \mu_1}{2\beta} \quad (6)$$

then

$$P_x^* = \frac{\alpha + C_m + \eta_1 + \mu_1}{2} \quad (7)$$

The leather manufacturer can achieve the optimal output at the government-guided price. Therefore, formulas 6 and 7 reflect the best response of the manufacturer to that price.

Recycler Model

In the recycling business, the recycler recovers waste leather produced by the manufacturer. Let C_n be the net cost of recycling a unit of waste leather, and s be the government subsidies on each unit of waste leather recovered by the recycler. Besides, we denote the unit inventory cost, the unit transport cost and the unit labour cost as η_2, ν and $\mu 2$, respectively. However, some of the waste leather recovered by the recycler cannot be converted into useful materials. Hence, the conversion rate is denoted as x, the unit scrap cost is denoted as ρ, and the scrap cost is denoted as $x\rho Q_c$.

The profit of the recycler is expressed as:

$$\pi = (s - P_w - C_n - \eta_2 - \nu - \mu_2)Q_c - \chi\rho Q_c \quad (8)$$

Thus, we have

$$Q_c = w + \varphi P_w \quad (9)$$

Under the Nash equilibrium

$$\frac{\partial \pi}{\partial P_w} = s\varphi - w - 2\varphi P_w - C_n\varphi - \eta_2\varphi - \nu\varphi - \mu_2\varphi - \chi\rho\varphi \quad (10)$$

we have

$$\frac{\partial \pi}{\partial P_x} = 0 \quad (11)$$

then

$$P_x^* = \frac{s\varphi - w - C_n\varphi - \eta_2\varphi - \nu\varphi - \mu_2\varphi - \chi\rho\varphi}{2\varphi} \quad (12)$$

and

$$Q_c^* = \frac{w + s\varphi - C_n\varphi - \eta_2\varphi - \nu\varphi - \mu_2\varphi - \chi\rho\varphi}{2} \quad (13)$$

Since the optimal rate of return appears when the recycler receives government subsidies, it is possible to find the optimal rate of return and the optimal recycling amount in the case of financial subsidies.

Integrated Model

Inspired by the idea of modern supply chain management, the authors pursue the maximum benefit of the whole system rather than that of a single node. Suppose the government subsidies is sQc and the tax is tQx, where t is the unit tax price. According to formula 2, not all waste leather is recovered by the recycler.

The unrecovered waste leather is:

$$(1 - \tau)Q_x \quad (14)$$

Meanwhile, if Ce is the indirect pollution cost of the unrecovered waste leather, and Cj is the indirect pollution cost incurred in the production and sale of new products, then the pollution cost of the entire supply chain is:

$$C_e(\tau Q_x - Q_c) + C_j Q_x \quad (15)$$

whereas the manufacturer's profit is:

$$\pi = (P_x - C_m - \eta)Q_x + Q_c P_w \quad (16)$$

and the recycler's profit is:

$$\pi = (s - P_w - C_n)Q_c \tag{17}$$

then, the profit of the entire supply chain is:

$$\pi_{ALL} = [(P_x - C_m - \eta_1 - \mu_1)Q_x + Q_c P_w] + [(s - P_w - C_n - \eta_2 - \nu - \mu_2)Q_c - \chi\rho Q_c] - sQ_c - [C_e(\tau Q_x - Q_c) + C_j Q_x] \tag{18}$$

EXPERIMENTAL

With Ce=22 and Cj=1.5, numerical experiments were performed on the recycling of waste leather produced in leather manufacturing process. The sensitivity of the parameters was analysed numerically, including the relationship between the sensitivity of the recycling amount to the rate of return ϕ and the profit, and the relationship between the unit inventory cost η1 and profit. The experimental results are shown in Figures 5 and 6.

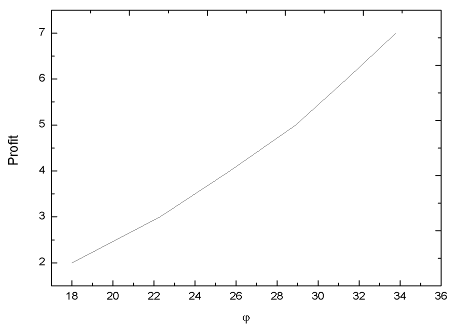

Figure 5. The relationship between the sensitivity of the recycling amount to the rate of return and the profit

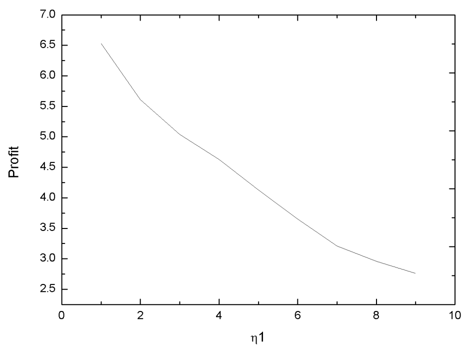

Figure 6. Relationship between the unit inventory cost and the profit

RESULTS AND DISCUSSION

As shown in Figure 5, the profit increases with the increase in φ, indicating that the recycler can recover more waste leather and the supply chain receives greater profit when the manufacturer takes concrete actions on waste leather recycling. According to Figure 6, the profit is negatively correlated with η_1. This means the unit inventory cost has a negative impact on the profit of the entire supply chain.

CONCLUSION

As an important part of China's economy, the leather industry is an engine of the rapid economic development. In recent years, however, the growth of the leather industry in China is under increasing strain. The reasons include but are not limited to the slowdown of demand, the lack of resources, environmental constraint, and soaring cost. In order to save resources, enliven the enterprises and revive the leather industry, this paper studies the recycling of the waste leather produced in leather manufacturing process, and establishes the relevant models.

Hereinto, the authors reviewed the research background, introduced China's leather industry, discussed the recycling of leather waste, established an integrated model, in which the recycler recovers the waste leather produced in leather manufacturing process, and conducted several numerical experiments. The results show that the recycling can increase the profit of the entire supply chain.

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COMPETENCE OF COORDINATION IN LOWER LIMBS OF CHILDREN AGED 3-6: CLUES FROM THEIR BACKWARD WALKING

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COMPETENCE OF COORDINATION IN LOWER LIMBS OF CHILDREN AGED 3-6: CLUES FROM THEIR BACKWARD WALKING

ABSTRACT. Since current literature does not explain how children aged 3-6 reacted when the walking direction was reversed or what its mechanism is, the aim of this study was to understand the mechanism of their 'Neuro-musculo-skeletal' systems in the process of direction changes, as well as its coordination features. The kinematics of forward walking (FW) and backward walking (BW) of 96 subjects were measured by the Coda motion system and their Euler angles in lower limb joints were first collected. According to the coordination algorithm, the phase angle (PA) in the knee and ankle and the continuous relative phase angle (CRP) between the two joints were calculated; further the mean, standard deviation (SD) and range of data for variables of PA and CRP were contrasted between FW and BW. All the statistical models were executed under SPSS with a significance level of 0.05 and a confidence interval of 95%. The results show that children in BW first had an unstable velocity in their ankles; further, PA in both their ankles and knees were distributed in a limited range. Meanwhile the key gait events were not obtained in BW in all age groups. A similar CRP was seen between FW and BW, but a significant difference existed between the two types of gait. The majority of the mean and range of PA and CRP were recorded with significant distinctions between FW and BW in each age group. Finally, significant gender differences existed in all variables of BW in each age group. Overall, although achieving the BW was easy for preschool toddlers (aged 3-6), but their coordination in lower-limb were still in developing and further fine tuning; moreover, their clues in backwarding also tell the detail of development in the 'Neuro-musculo-skeletal' system.

KEYWORDS: backward walking, lower limb coordination, continuous relative phase, phase angle, healthy children

CAPACITATEA DE COORDONARE A MEMBRELOR INFERIOARE LA COPIII DE 3-6 ANI: INDICII DATE DE MERSUL ÎNAPOI

REZUMAT. Deoarece literatura actuală nu explică modul în care copiii cu vârste cuprinse între 3 și 6 ani reacționează când se inversează direcția de mers sau care este mecanismul, scopul acestui studiu a fost de a înțelege mecanismul sistemelor neuro-musculo-scheletice ale acestora la schimbarea direcției, precum și caracteristicile de coordonare ale acestora. S-a măsurat cinematica mersului înainte și a mersului înapoi în cazul unui număr de 96 de subiecți utilizând sistemul Coda motion și colectând mai întâi unghiurile Euler ale articulațiilor membrelor inferioare. Conform algoritmului de coordonare, s-au calculat unghiul de fază (PA) la genunchi și gleznă și unghiul de fază relativă continuă (CRP) între cele două articulații; în continuare, s-au comparat abaterea standard medie (SD) și intervalul de date pentru variabilele PA și CRP între mersul înainte și mersul înapoi. Toate modelele statistice au fost executate cu programul SPSS cu un nivel de semnificație de 0,05 și un interval de încredere de 95%. Rezultatele arată că la copiii care au mers înapoi s-a observat mai întâi o viteză instabilă la nivelul gleznelor; în plus, unghiurile de fază la glezne și genunchi au fost distribuite într-un interval limitat. În același timp, momentele cheie din timpul mersului nu au fost obținute în cazul mersului înapoi în toate grupele de vârstă. O valoare similară a CRP a fost observată comparând mersul înainte și mersul înapoi, dar a existat o diferență semnificativă între cele două tipuri de mers. Majoritatea mediilor și intervalelor PA și CRP au fost înregistrate cu distincții semnificative între mersul înainte și mersul înapoi în fiecare grupă de vârstă. În cele din urmă, au existat diferențe semnificative de gen în toate variabilele mersului înapoi din fiecare grupă de vârstă. În ansamblu, deși realizarea mersului înapoi a fost ușoară pentru preșcolari (cu vârste cuprinse între 3 și 6 ani), coordonarea membrelor inferioare este încă în curs de dezvoltare și ajustare; în plus, indiciile date de mersul înapoi, dezvăluie, de asemenea, detalii ale dezvoltării sistemului neuro-musculo-scheletic.

CUVINTE CHEIE: mers înapoi, coordonarea membrelor inferioare, fază relativă continuă, unghi de fază, copii sănătoși

LA CAPACITÉ DE COORDINATION DES MEMBRES INFÉRIEURS CHEZ LES ENFANTS DE 3-6 ANS: INDICES DE LEUR MARCHE ARRIÈRE

RÉSUMÉ. Étant donné que la littérature actuelle n'explique pas comment les enfants âgés de 3 à 6 ans réagissent en inversant le sens de la marche ou quel est le mécanisme, le but de cette étude est de comprendre le mécanisme de leurs systèmes neuro-musculo-squelettiques dans le cas du changement de direction, ainsi que leurs caractéristiques de coordination. On a mesuré la cinématique de la marche avant et de la marche arrière pour un total de 96 sujets en utilisant le système Coda motion et premièrement on a recueilli les angles d'Euler des articulations des membres inférieurs. Selon l'algorithme de coordination, on a calculé l'angle de phase (PA) chez les genoux et les chevilles et l'angle de phase relative continue (CRP) entre les deux articulations ; puis on a comparé l'écart-type moyen (ET) et la plage de données pour les variables PA et CRP entre la marche avant et la marche arrière. Tous les modèles statistiques ont été exécutés avec le programme SPSS avec un niveau de signification de 0,05 et un intervalle de confiance de 95%. Les résultats montrent que chez les enfants qui ont marche arrière, une vélocité instable de la cheville a été observée premièrement ; de plus, les angles des chevilles et des genoux étaient répartis dans une gamme limitée. Dans le même temps, les moments clés de la marche n'ont pas été obtenus pour toutes les groupes d'âge. Une valeur de CRP similaire a été observée en comparant la marche avant et la marche arrière, mais il y avait une différence significative entre les deux types de marche. La plupart des moyennes et intervalles PA et CRP ont été enregistrés avec des distinctions significatives entre la marche avant et la marche arrière dans chaque groupe d'âge. Enfin, il y avait des différences significatives entre les sexes dans toutes les variables de la marche arrière dans chaque groupe d'âge. Dans l'ensemble, bien que la réalisation de la marche arrière était facile pour les enfants d'âge préscolaire (âgés de 3 à 6 ans), la coordination est encore en cours de développement et d'ajustement ; en outre, les indices de la marche arrière révèlent également des détails du développement du système neuro-musculo-squelettique.

MOTS CLÉS : marche arrière, coordination des membres inférieurs, phase relative continue, angle de phase, enfants en bonne santé

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INTRODUCTION

Regarding movement, walking is under the control and coordination of the 'Neuro-musculo-skeletal' system, which varies at different development stages. There are two stages in a child's development: The first stage spans the first 5–6 months after a toddler starts to walk, leading to rapid changes in terms of kinematics and kinetics [1]. The second stage represents a further fine-tuning of the gait pattern, lasting until the age of 8. Ages 3-6 [2] were the critical ages for building a way of motion which would affect their gait and posture later in their life. Feet are the only parts of the human body which have contact with the ground, and they play a major role in accepting load while in the stance phase and then in transferring this load to other parts of the lower limbs; but how the 'Neuro-musculo-skeletal' mechanism coordinates the motion of the lower limbs when the walking direction changes was still not clear [3, 4].

It was acknowledged that neural control of forward walking (FW) and backward walking (BW) might largely originate from the same basic neural circuitry [5] and BW often presents a contrary motion cycle from that of FW [6]. In terms of FW, Hallemans studied the gait pattern of young toddlers and suggested that, after one year of independent walking, children's gait pattern had transferred from a flat foot to a heel contact one [7]; similarly, further foot development was confirmed by Bosch *et al*. [8] In terms of BW, Meyns [5] wanted to explain to what extent development plays a role in the maturation of neural control of gait in different directions. They first measured and contrasted the kinematics of both lower and upper limbs between the FW and BW; they then concluded that upper and lower limb kinematics of FW correlated highly to reversed BW kinematics in children. Moreover, Ledebt [9] indicated that children initially fixed their arms in a high guard position (external rotation in the shoulder, flexed elbows and hands at shoulder height) which then gradually changed to a low guard position as age increased (arms extending along the body without actively swinging). Fritz [10] contrasted the FW and BW in the adult and elderly populations and then recommended that clinicians were encouraged to assess BW, particularly BW velocity, as part of mobility examinations to identify those individuals in the elderly population at risk of falling. In addition, in terms of dynamics for adults, Lee *et al*. [11] found that there are significant differences in the ankle, knee and hip moments between FW and BW. However, whether a toddler at the beginning of age 3 has already mastered motion control in varied directions and achieved a better coordination or not, or to what extent of development before age of 6 the toddler could freely deal with those tasks and challenges were not seen in current literature.

Therefore, the aim of this study was to quantify the competence of coordination in lower limbs of children aged 3-6 by contrasting their gait variances between forward and backward walking, so as to understand the mechanism of the 'Neuro-musculo-skeletal' system in the process of direction changes. According to literature, the following hypothesis was proposed: since after independent walking, young toddlers were more familiar with the varied gait environments; hence, similar coordination strategies in BW would be found for children aged 3-6 and their competences in backward walking have been well developed.

METHOD

Subjects

In total, 96 healthy children between the ages of 3 and 6 were recruited in this study. The criteria for inclusion is shown below: (1) a body mass index (BMI) consistent with the BMI standard for normal Chinese children [12]; (2) no foot deformities or injuries; (3) the ability to walk independently; (4) no abnormal gait patterns, such as a crouching gait or equinus. All the measurements were executed after the details of this study were introduced to children's parents and their formal approvals were obtained. Moreover, all the measurements and procedures were registered in the University Ethic Committee followed the principles of Helsinki Declaration.

Motion Capture of Children's Lower Limbs

The Coda Motion System (Coda Motion cx1, Charnwood Dynamics Ltd., United Kingdom) was used in this study to obtain the spatiotemporal parameters of children's lower limbs in normal walking. Two collectors were aligned on the two sides of the six-meter-long walking track, facing at an angle of 120 degrees. Twenty key positions were first marked for both sides of lower limb according to the Human Analysis Protocol of system (Fig. 1). Then Euler angle (EA) (θ) and angular velocity (ω) in zxy coordination sequence were calculated for knee (θ (OAB) / ω (OAB)) and ankle (θ (ABD) / ω (ABD)) using the Odin software (V1.02, Charnwood Dynamics Ltd., United Kingdom).

All subjects were asked to change into tight clothes when they arrived; and then the same researcher set markers. A three to five minute warm-up period was provided for their familiarization. Warm-up was composed by motion of several squatting and walking in the track; all those efforts were to eliminate the variance in measure. Afterwards, subjects walked at their own selected speed while the data was simultaneously recorded. At least five successful trials were required for each foot, where a success trail was defined as more than 90% data completion were achieved for all markers and at least two complete gait cycles were obtained.

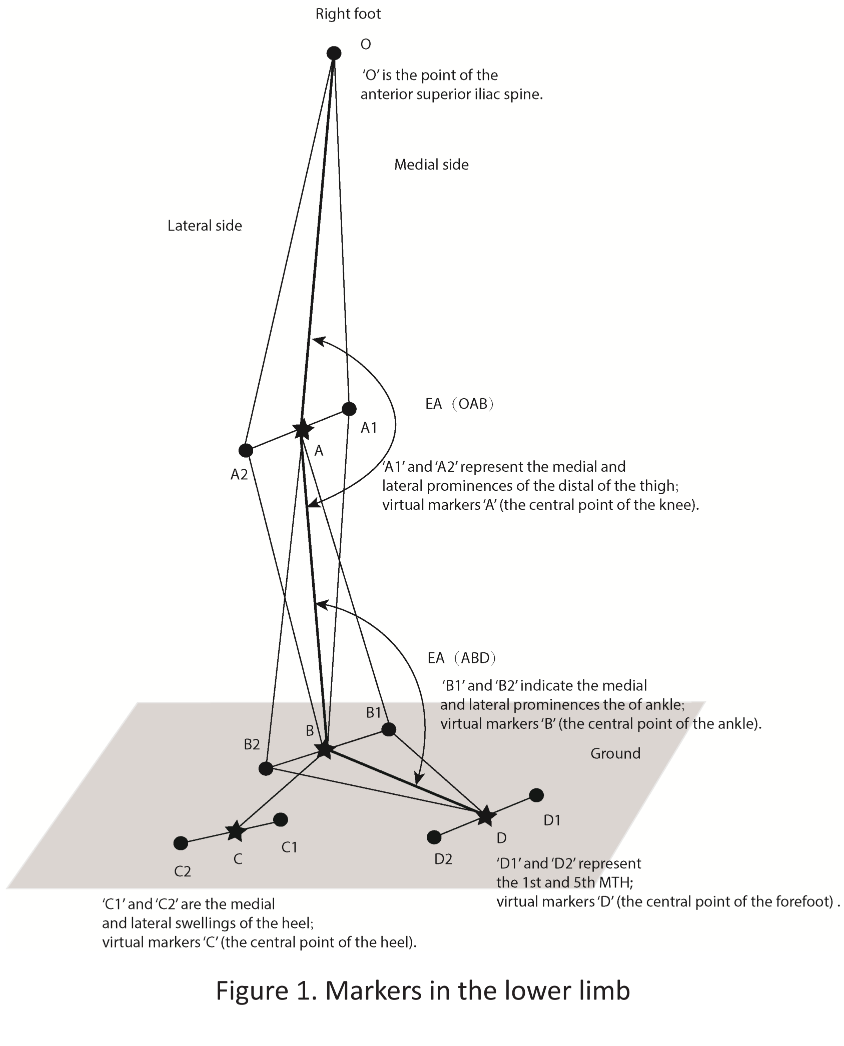

Figure 1. Markers in the lower limb

Data Processing

According to the protocol developed by Clark [13], Miller [14] and Ross [15], phase angle (PA) of knee and ankle and continuous relative phase (CRP) between the knee and ankle ($\theta_{CRP}(K-A)$) were chosen for further analysis and they were processed according to EQ 1-4. An in-phase indicated that θ_{CRP} was within 0 and 30 degrees and the two joints rotated either clockwise or anti-clockwise simultaneously; while that of anti-phase was between 150 and 180 degrees and the two joints rotated in opposite directions [15]; other angles were classified as out-phase. Consistencies and coordinative stability in terms of PA and CRP were quantified by their mean values over the gait cycle, standard deviations (SD) and range of motion (ROM), which was defined as the difference between the maximum and minimum of the elevation angle trace [5].

$$\bar{\theta} = 2\left[\frac{\theta - \min(\theta)}{\max(\theta) - \min(\theta)}\right] - 1 \quad (1)$$

$$\bar{\omega} = \left[\frac{\omega}{\max(|\omega|)}\right] \quad (2)$$

$$\varphi(i) = \tan^{-1}\left[\frac{\bar{\omega}(i)}{\bar{\theta}(i)}\right], i = 1,2,\ldots,n \quad (3)$$

$$\theta_{CRP}(i) = |\varphi_1(i) - \varphi_2(i)| \quad (4)$$

All the time series data were first filtered by a 6 Hz cut off and then the time period of a complete gait cycle was selected; further a quintuple spline procedure [16] was used to create a 100 point time-normalized gait cycle (GC); then, time axis of backward walking were reversed and its gait cycle was modified as a reversed one (MGC).

Statistical Analysis

Intra-subject data was first averaged, and then inter-subject data. One sample K-S model was used to the test normal distribution, and all data were approved to be within normal distribution. However, distinctions existed between the left and right foot as examined by the independent T test; thus, only the right foot was selected for further analysis. Variations between FW and BW in SD and ROM were explored by the Paired-t test; further, influences of gender was assessed by the ANOVA. All statistical models were executed under SPSS with a significance level of 0.05 and a confidence interval of 95%.

RESULTS

The mean age is 4.6 ± 1.1 years, the mean body weight is 17.4 ±2.8 Kg, the mean height is 105.7 ± 7.4 cm and the mean BMI is 15.6 ±0.5. The details were shown in Table 1.

Table 1: Characteristics of all age groups children

	Age 3	Age 4	Age 5	Age 6
N	27	34	28	7
Gender (M/F)	15/12	16/18	11/17	4/3
Age (years)	3.5±0.4	4.4±0.3	5.5±0.3	6.0±0.0
Weight (kg)	15.7±2.2	17.3±1.7	18.2±2.1	22.2±3.1
Height (cm)	99.3±5.5	105.3±3.4	110.0±4.3	116.7±3.4
BMI	15.8±1.3	15.6±1.2	15.0±1.1	16.3±2.2

Relationship Between Euler Angles and Angular Velocities

In FW, the Euler angles and angular velocities of knees and ankles were distributed in a reasonable range. However, the ankle in BW fluctuated unstable, with a particularly higher velocity in each age; additionally, with the exception of age 3, knee control in BW was constrained within a specific range (Figure 2).

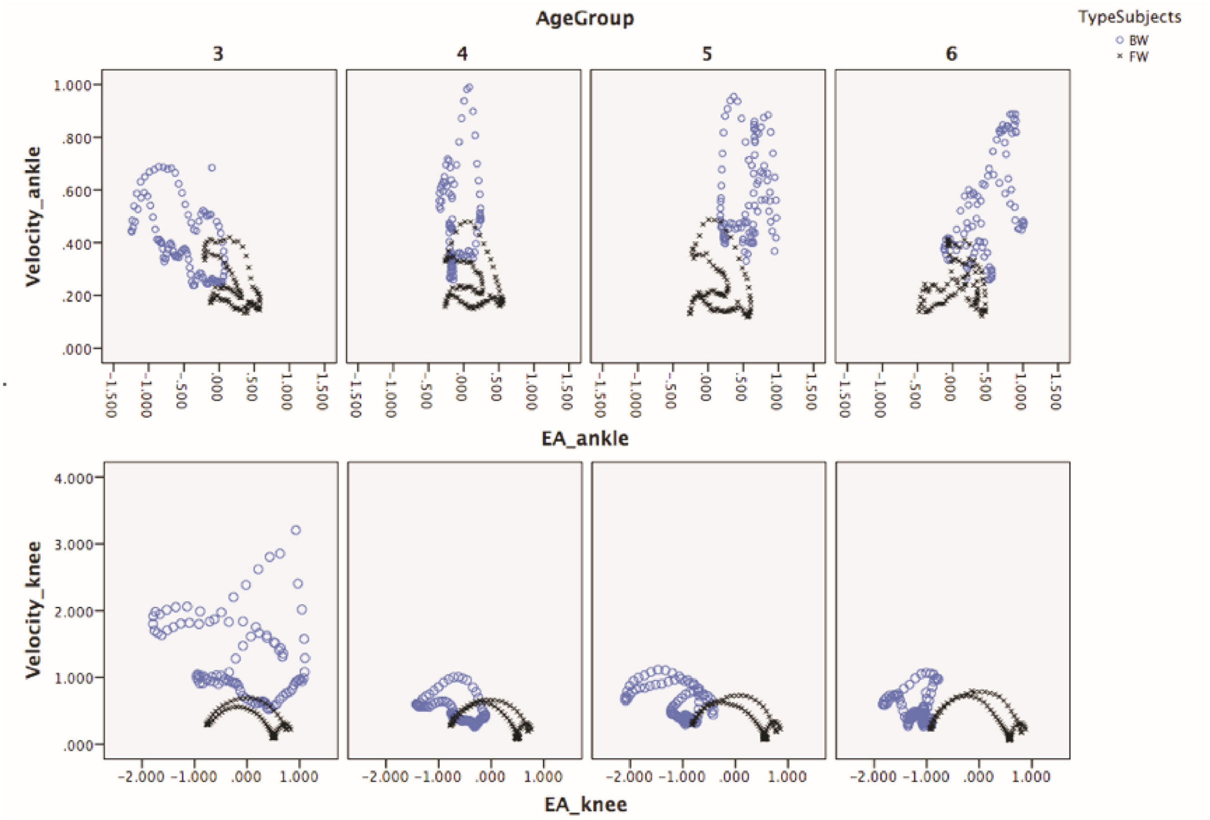

Figure 2. Scatter plot of Euler angle and angular velocity in ankle and knee

Analysis of the Phase Angle and Relative Phase Angle

Explicit knee and ankle movement in sequence with key gait events were seen in FW; further the knee was in extension at the beginning of the gait cycle. Before it kept this status in order to maintain stability in middle stance phase, it flexed in an initial heel contact to assist the cushion. Meanwhile, the ankle pivoted the body to move forward rapidly after touching the ground, and it shifted in the posture of dorsiflexion and plantarflexion. Whereas, FW-BW variations existed in both PA and CRP (Fig. 3) and both knee and ankle were lack of key gait events while BW, where a limited motion was found as well; further both the PA of knee and ankle were distributed within a -25 to 25 relative angle, but their CRP was similar with that of the FW.

The distribution of PA and CRP could be further explained by SD and ROM. A limited ROM first found for the knee and ankle in each variable during the BW. Significant FW-BW differences in SD and ROM of PA were found for each age group (p=0.000 for all) (Table 2), with the exception of the ROM of PA-Knee (P=0.45 for 4y, P=0.23 for 5y, P=0.17 for 6y).

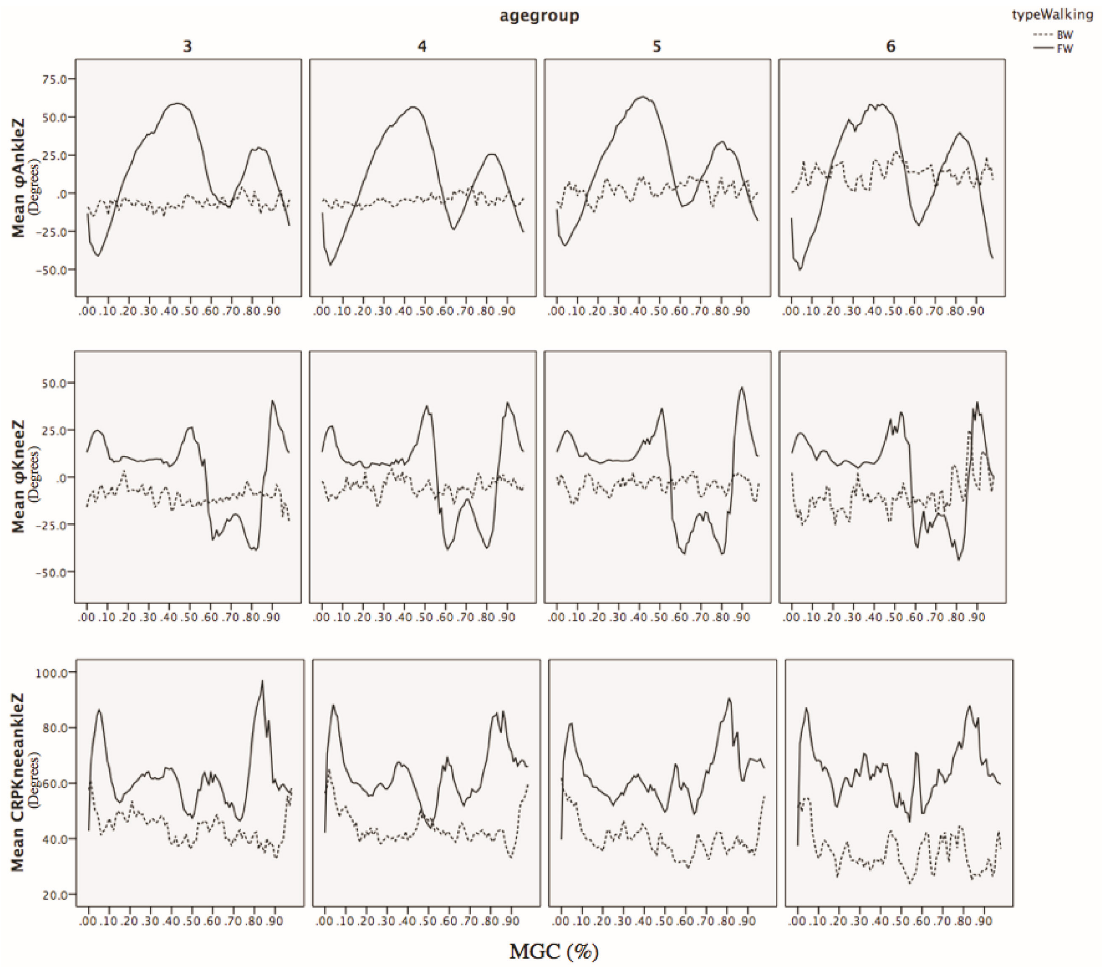

Figure 3. Distribution of the phase angle (PA) and relative phase angle (CRP) of the ankle joint and knee joint in the normalized gait cycle

Table 2: Differences between BW and FW in mean, SD and range

		3y			4y			5y			6y		
Variables	Parameters	BW	FW	sig.	BW	FW	sig.	BW	FW	sig.	BW	FW	sig.
	Mean	-9.9	3.1	0.000*	-5.2	3.6	0.000*	-4.1	3.6	0.000*	-9.7	3.1	0.000*
	SD	19.5	28.9	0.609	21.1	29.8	0.429	24.5	33.4	0.000*	24.2	29.2	0.001*
PA_KneeZ	Range	135.3	175.0	0.000*	155.0	174.0	0.454	157.3	179.0	0.225	143.5	162.0	0.173
	Mean	-6.8	15.8	0.000*	-4.6	9.9	0.000*	2.0	17.9	0.000*	12.7	14.0	0.463
	SD	21.5	48.0	0.000*	17.1	46.3	0.000*	22.7	47.4	0.000*	18.5	44.0	0.000*
PA_AnkleZ	Range	145.9	179.0	0.000*	116.9	178.0	0.000*	157.1	180.0	0.000*	105.3	167.0	0.000*
	Mean	43.9	62.2	0.000*	44.0	63.5	0.000*	40.1	63.1	0.000*	35.2	64.4	0.000*
	SD	22.4	25.7	0.210	21.9	24.9	0.003*	21.7	27.0	0.048*	20.2	21.2	0.000*
CRP(Knee_ankle)Z	Range	131.5	160.0	0.000*	150.1	160.0	0.000*	163.6	177.0	0.000*	121.6	137.0	0.000*

* Significant differences lower than 0.05

Analysis of Gender Differences

Gender differences in FW were clear in references [17]. In terms of BW, girls age 3 were recorded with significant differences in their ankles compared with those of boys (p=0.000 for PA-ankle), where boys had limited motion in 15-55% MGC. Similar results were found in age 4 (P=0.000 for PA-ankle). In 50-90% MGC, significant differences in the PA of knees (p=0.02) were found between boys and girls aged 5 and 6 recorded with a higher PA-Knee (p=0.00) during the entire gait cycle. Finally, significant gender differences were found in age 3 (p=0.000), 4 (p=0.008) and 6 (p=0.001) in CRP variables.

DISCUSSIONS

In this study, 96 healthy children aged 3-6 performed forward and backward walking; the kinematic data were collected by a 3D motion system. According to an algorithm of the coordinates, PA and CRP in the knee and ankle were evaluated and further contrast between FW and BW was made. Our results show that children in BW had an unstable velocity in their ankles; further, the PA in both the ankle and knee had a limited range of distribution. Meanwhile, the key gait events were not shown in BW in all ages groups. Similarly, the CRP of BW was recorded as in FW, but with significant differences between the two types of gait. The majority of the mean and range of the PA and CRP were recorded with significant differences between FW and BW in each age group. Moreover, significant gender differences existed in all variables of each age group in BW.

Pieter [5] reported that most of the gait features in FW are confined in BW, and they also indicated that coordination stability of BW was slightly attenuated. Nevertheless, they summarized that the FW/BW differences were slight for schoolchildren. However, in our study, BW was shown to be quite different from FW for preschool children (aged 3-6). Firstly, a higher velocity of ankle rotation was obtained; this finding implied that although walking speed was lower in BW, which was similar with that of a blindfolded subject [18], the motion of the ankle seemly sped up, so as to adjust the ground touching with higher mobility. Secondly, we also recorded limited motion in both the ankle and knee, which was controversial with regard to current understanding that a reduction of the walking speed increases the range of joints' motion in order to maintain the rhythm of walking and achieve proper balance in motion. In BW, there was a lack of a clear peak plantar flexion in the ankle, but clear dorsiflexion during striking periods; meanwhile, similar results were found for the knee. To some extent, our results indicated that the heel-strike gait was missing, so it required a strong muscle to provide a cushion, such as the tibialis anterior in the shank; consequently, a peculiar pattern was found in the BW [19].

In terms of CRP, the ankle and knee of FW were always in the status of out-phase; whereas, BW was recorded partly in the in-phase. Although in-phase or out phase did not imply better or inferior coordination, FW usually represented better coordination, as well as a lower energy cost. In this viewpoint, BW was a type of gait with a high energy cost, and it was usually performed with uncertainty to some extent, which could be proved by the fluctuating curves in BW. Due to the different protocols, our results were not consistent with the those of Pieter's [5]. Generally, similar coordination strategies in FW-BW were found in children age 3-6, but variations existed between two walking types; hence, our hypothesis was partly approved.

Current literature [5] further shows that age has a moderate effect on the gait of school-aged children, such as the range of lower limbs movement, but finally concludes that the development of school-aged children has already completed and limited progress in the gait of multi-direction movement was gained. This finding was confirmed by Dietz [20] who demonstrated that the nerve control of school-aged children can be easily switched between FW and BW by using EMG-analysis. In our cases, gender differences existed in each age group. Boys 3 to 4 years of age showed a limited range of ankle motion, while, at age 5 and 6, major differences were found in the knees. Girls performed at a higher PA-Knee than that of boys. These phenomena might be due to a heavier bodyweight in boys and taller body height in girls, which could shorten the range of ankle motion [8], but increase that of the knee.

Although the above results further indicate the gait mechanism and coordination of different exercise directions of 3-6 year old children, there are some limitations: (1) children chose their preferred walking speed during measurement; although the walking speed affected the amplitude of motion, in this study, normalization was made to diminish the influence of speed; (2) markers were set on tight clothing rather than skin, which would cause movement of the marker while walking; in order to overcome this defect, a 6 Hz cut off strategy was applied in the period of data processing; (3) broad categories of age were chosen in our study, and this would ignore details of development within one year of age; however, classification into a one year interval could give a view of children's development in coordination.

CONCLUSIONS

Overall, although achieving the BW was easy for preshcool todders (aged 3-6), but their coordination in lower-limb were still in developing and further fine turning; moreover, their clues in backwarding also tell the detail of develop in the 'Neuro-musculo-skeletal' system.

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CHARACTERISTICS OF TEENAGERS' GAIT AND FOOT PRESSURE DISTRIBUTION IN MID-LONG DISTANCE RUNNING

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CHARACTERISTICS OF TEENAGERS' GAIT AND FOOT PRESSURE DISTRIBUTION IN MID-LONG DISTANCE RUNNING

ABSTRACT. By using Rs-scan insole pressure test system, this article measures and analyses teenagers' gait and foot pressure in mid-long distance running and conducts quantitative experiment to mid-long distance running by selecting master, level 1&2 teenage runners to form the experiment group and ordinary university students to form the control group. Firstly, it briefly introduces the development of research on running gait biology and foot pressure test system. By dividing feet pressure into various areas and using effective experimental method, it designs and measures such parameters as gait cycle & phase, Center of Pressure (COP) track, Pressure-Time Integral (PTI), Partition Peak Pressure (PP), etc. Finally, it reaches relevant conclusions through comparative analysis of measurement data. This research provides theoretic support and data basis for research on foot pressure distribution, mechanism of force in different phases of sport and prevention of sports injury.

KEY WORDS: mid-long distance running, rs-scan, gait, foot pressure distribution characteristics, contrast experiment

CARACTERISTICILE MERSULUI ȘI ALE DISTRIBUȚIEI PRESIUNII PLANTARE LA ADOLESCENȚI ÎN TIMPUL ALERGĂRII PE DISTANȚĂ MEDIE ȘI LUNGĂ

REZUMAT. Acest articol măsoară și analizează mersul și presiunea piciorului la adolescenți în timpul alergării pe distanță medie și lungă utilizând sistemul de testare a presiunii branțului Rs-scan și efectuând un experiment cantitativ de alergare pe distanță medie și lungă prin selectarea unor adolescenți la nivel 1, 2 și expert, care au format grupul de experiment și a unor studenți obișnuiți pentru a forma grupul martor. În primul rând, se prezintă pe scurt evoluția cercetărilor privind biomecanica alergării și sistemul de testare a presiunii piciorului. Prin împărțirea piciorului în diferite zone de presiune și prin utilizarea unei metode experimentale eficiente, se proiectează și măsoară parametri cum ar fi ciclul și faza de mers, traiectoria centrului de presiune (COP), integrala presiune-timp (PTI), presiunea maximă pe zone (PP) etc. În cele din urmă, se ajunge la concluzii relevante prin analiza comparativă a datelor măsurate. Această cercetare oferă sprijin teoretic și o bază de date pentru cercetarea privind distribuția presiunii piciorului, mecanismul forței în diferite faze ale sportului și prevenirea rănilor sportive.

CUVINTE CHEIE: alergare pe distanță medie și lungă, Rs-scan, mers, caracteristici de distribuție a presiunii piciorului, experiment de contrast

LES CARACTÉRISTIQUES DE LA MARCHE ET DE LA DISTRIBUTION DE LA PRESSION PLANTAIRE CHEZ LES ADOLESCENTS PENDANT LA COURSE DE MOYENNE ET LONGUE DISTANCE

RÉSUMÉ. Dans cet article on mesure et on analyse la marche et la pression du pied chez les adolescents pendant la course de moyenne et longue distance en utilisant le système de test de la pression Rs-scan et on réalise une expérience quantitative de la course de moyenne et longue distance en sélectionnant des coureurs adolescents au niveau 1, 2 et expert, qui ont formé le groupe d'expérimentation et quelques étudiants réguliers pour former le groupe témoin. Tout d'abord, on présente brièvement l'évolution de la recherche sur la biomécanique de la course et le système de test de la pression du pied. En divisant les pieds dans de différentes zones de pression et par l'utilisation d'une méthode d'expérimentation efficace, on a conçu et mesuré des paramètres tels que le cycle et la phase de la marche, la trajectoire du centre de pression (COP), l'intégrale pression-temps (PTI), la pression maximale dans les zones (PP), etc. Enfin, des conclusions pertinentes sont obtenues par l'analyse comparative des données mesurées. Cette recherche fournit un soutien théorique et une base de données pour la recherche sur la distribution de la pression du pied, le mécanisme de la force dans diverses phases du sport et la prévention des blessures sportives.

MOTS CLÉS: course de moyenne et longue distance, Rs-scan, marche, caractéristiques de distribution de la pression du pied, expérience de contraste

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INTRODUCTION

Running is the most common sport and the major event of athletics. It plays an important role in such big sport events as the Olympics [1]. As exercises have become more and more popular in China and people have increased their exercise awareness, increasingly more adolescents have chosen mid-long distance running to do fitness. Meanwhile, athletes are eager to improve their competition results in this sport. Therefore, in order to do the exercise of mid-long distance running scientifically and reduce sports injury, it is of significance to study the biomechanical characteristics of adolescents in mid-long distance running so as to obtain quantitative experimental data and qualitative theoretic analysis [2].

In recent years, it has been a hot field to study biomechanics of the foot movement, and running has received more and more attention as a branch of foot mechanics, which has been extensively studied in such applications fields as sports, medical care and engineering [3]. However, stating late, the study of running has been in lack of systematic research on different types of running including mid-long distance running.

Research on foot gait and stress distribution during mid-long distance running is of guiding significance not only to doing sports scientifically, but also to designing running shoes, thus having economic benefits [4]. Therefore, this article studies the foot biomechanical characteristics of adolescents in mid-long running. It selects three grades (master, level 1&2) of mid-long distance runners as subjects, and ordinary college students to form the control group, thus making the experiment measuring data more contrastive and meeting the requirements of guiding different groups [5]. It briefly introduces biomechanics of running gait and compares the functions of different foot pressure test systems as well as their application in foot pressure study. Rs-scan insole pressure test system was finally chosen to record and measure people's gait character and foot pressure distribution in different phases of mid-long distance running [6]. On one hand, the study will help athletes to seek for more scientific methods in mid-long distance running. On the other hand, it will help ordinary enthusiasts to refer to foot characteristic of athletes and keep correct running posture, thus protecting their feet. In addition, the study will be of guiding significance to improve technical level and self-innovation capability of China's sports shoes manufacturing industry.

BACKGROUND OF THE STUDY

Study on Biomechanical Characteristics of the Running Gait

Individualized study of running started in the 20th century. At the beginning it mainly centered on study of full-speed and short running while distance running and endurance run did not obtain enough attention. After "the fever of run" emerged, middle-distance running was gradually studied further. Development of biomechanical study on running can be divided into 3 phases: enlightenment period, foundation period, and development period [7].

After Newton found the Three Laws of Motion in the 17th century, relevant scholars laid the foundation of Exercise Physiology on the basis of them. That was the enlightenment period. During the foundation period, the foundation of inverted pendulum model assumption laid the theoretic frame of Gait Biomechanics [8]. Successively invention of velocimeter, accelerometer, force platform, photographic and mathematical method of gait study initiated a new direction in the fields of sports research. In development period, fast expansion of computer technology spawned numeric simulation algorithm and sensor pressure-sensing test equipments, thus improving preciseness and depth of research field [9].

Running Sports Research Problems and Research Prospects

The gait biomechanics run as an important branch of sports biomechanics, contains rich content and valuable research results and has formed a complete theoretical framework and knowledge system. It has important guidance in sports, medical and engineering fields. Domestic research in this field started late. The current research focused on clinical rehabilitation. The research results were also fragmented and not systematic. The lack of basic theories severely restricted the improvement of research in the application field. At present, researches on sporting events such as walking, long jump/ triple jump, pole vault, hurdles, etc. are mostly focused on kinematics. The analysis of mechanics is rarely reported, and no foot three-dimensional force and pressure distribution feature models of the above sports items have been found [10].

With the maturation of plantar pressure measurement techniques, it has expanded new application prospects and research areas in clinical biomechanics, human ergonomics and sports biomechanics and other areas. The data of plantar pressure measurement will provide new methods and technologies for dynamic measurement and evaluation of various types of walking, running, casting, balancing movements, supporting movements, take-off and landing movements. Combined with foot scanning technology, it is expected to provide a reliable basis for the design of sports shoes for different projects and the design of individual sports shoes for elite athletes.

STUDY METHOD

Object of Study

14 elite mid-long distance runners were selected as subjects of test group. Among them, there were 4 male athletes with an average height of 174 cm, the average exercise age was 4.75 years and the average weight was 61.5 kg. Meanwhile, 10 were female athletes and the average height was 167.7 cm, the average exercise age was 5.4 years and the average weight was 49.8 kg.

8 ordinary college students were selected to form the control group. Eight ordinary universities were selected as the control group for this study. Among them, there were 3 males with an average height of 171 cm and an average weight of 67.3 kg. Meanwhile, 5 female athletes had an average height of 168 cm and an average weight of 53.4 kg. No exercise age was found in the control group.

Instruments and Facilities

1. Rs-scan insole force system, 400 sensors on each foot, sensor volume 0.5cm*1cm, sampling frequency 500Hz, sampling time 8ms.

2. Laser Doppler Anemometer (LDV) and camera.

Testing Method and Steps

Testees need to finish mid-long distance running of 10000m within 30 minutes wearing Rs-scan insoles and uniform sports shoes. Before test instructions and objectives were explained to them. Data were recorded during test and saved for analysis.

Test steps were as below: register testee's information - do preparation, warm-up and give instructions - install test instruments - pretest - test - read and save data - remove instruments and check insole conditions. Test instruments were installed and connected as shown in Figure 1.

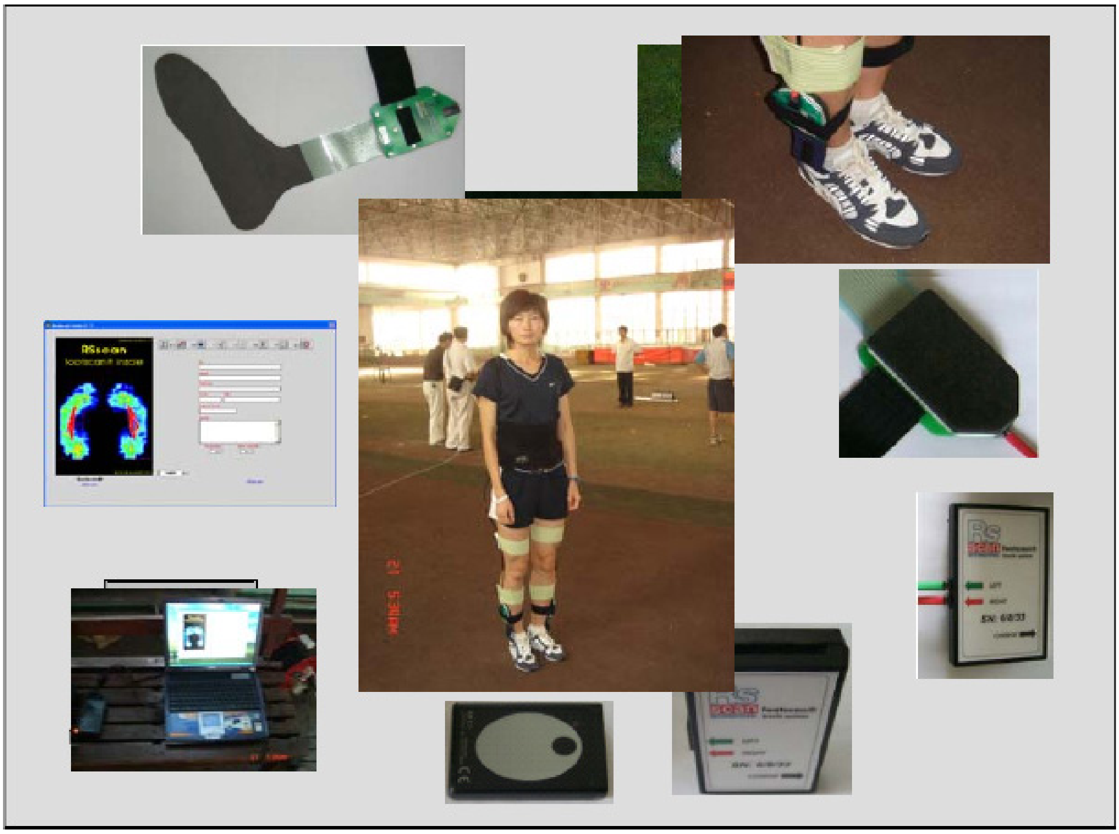


Figure 1. The test instrument installation and connection diagram

Foot Pressure Test Area

The plantar can be divided into 10 test partitions, T1, T2-T5, M1-M5, MF, HM. Toe 1 indicates the thumb, Toe2-Toe5 represents the 2nd-5th phalanxes, and Meta1-Meta5 stands for the 1st-5th metatarsal bones. Midfoot means middle part of foot, Heel Medial indicates inside of heel, and Heel Lateral means outer side of heel [12]. Figure 1 is the foot pressure test area schematic diagram.

8 sensor measuring points were set up respectively at the thumb, 1st, 3rd and 5th phalanxes, insides and outsides of instep & heel [13].

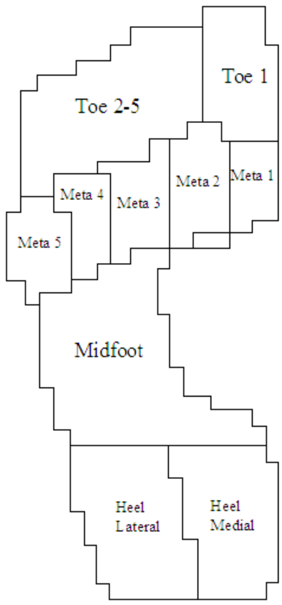


Figure 2. Foot pressure test area schematic diagram

RESULTS AND DISCUSSIONS

Gait and Its Phase & Cycle

Table 1: The step phase and cycle of the experimental and control groups run test

Parameters	Level 2 (n=6) Mean ± SD	Level 1 (n=5) Mean ± SD	Master (n=3) Mean ± SD	Average (n=14) Mean ± SD	Ordinary Mean ± SD
Pace	5.5 ± 0.1	5.44 ± ± 0.2	5.49 ± ± 0.3	5.4 ± ± 0.4	4.46 ± 0.6
Step size	291.5 ± ± 7.1	300 ± ± 15	324 ± 22	299 ± ± 18	257 ± 29
Step time	582 ± 8.1	607 ± ± 14.5	649 ± 16.5	595 ± ± 14.8	612 ± 38.8
Step frequency	1.72 ± ± 0.01	1.65 ± 0.03	1.54 ± ± 0.03	1.67 ± 0.04	1.50 ± 0.09
Support time	172 ± 6.5	168 ± 9.1	167 ± ± 12.3	170 ± ± 9.3	182 ± ± 16.4
Hang Time	118 ± ± 9.6	134 ± 19.5	157 ± ± 20.9	127 ± ± 17	144 ± 14.5
Time ratio	1.45 ± 0.11	1.25 ± 0.10	1.07 ± ± 0.06	1.33 ± 0.1	1.25 ± 0.17

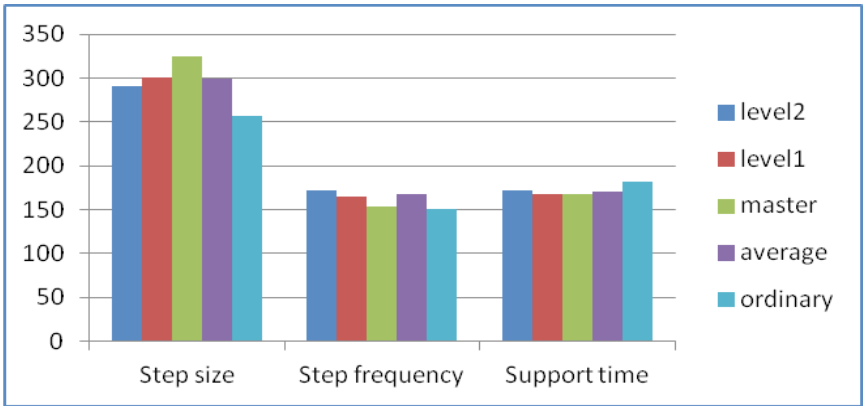


Figure 3. The compare of step size, frequency, support time of each group

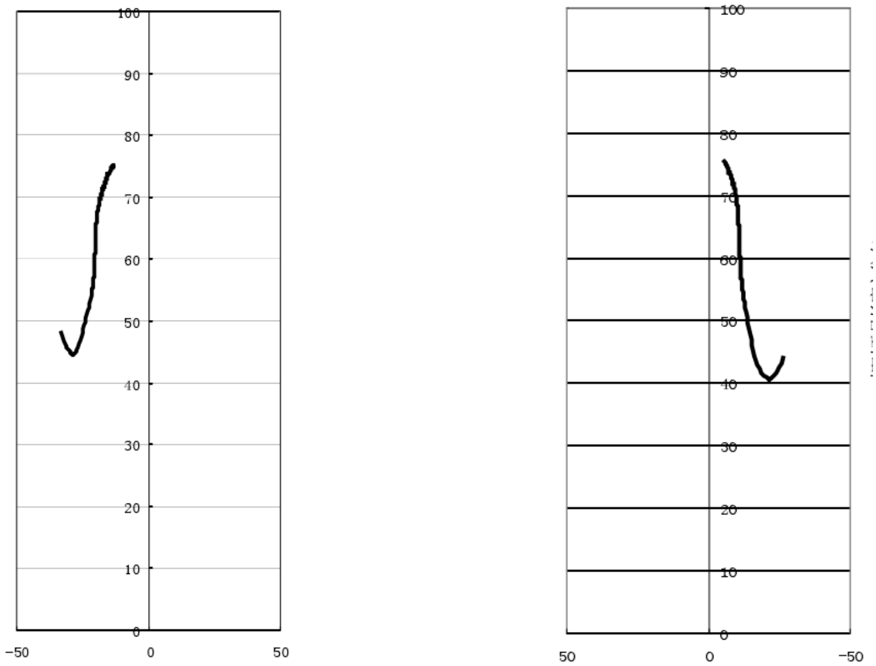
According to running posture and its technique cycle, running can be divided into 3 key phases: landing phase, stance phase, and kick-off phase. From data below it can be seen that obvious gap exists in step speed, step size, treading time, support time and step frequency. In addition there's difference of various degrees between different groups within experimental group and between experimental group and control group in terms of step size, step frequency, and support time, which indicates that these 3 are the effective and sensitive indicators to analyze middle-distance running technique.

It can be known from the figure above that stance time of athletes is shorter than that of ordinary teenagers while their step frequency and size are longer than the latter.

Analysis of Foot Pressure in Running

COP Track of Foot Pressure

Center of Pressure (COP) is the working point of joint forces in the plantar. It reflects the general distribution of pressure in the plantar. Here we take middle of the back heel as zero point, the line from zero point to head of the 2nd metatarsal phalangeal joint as vertical axis, front as positive direction of the Y-axis, vertical with which the line passing zero point we take as X-axis, and the inside of foot as positive direction of the X-axis [14]. Foot length and width is normalized to reduce impact of foot shape. The point with big inflection is chosen as the start of landing and kick-off.



(a) left foot COP track (b) right foot COP track

Figure 4. Athlete's foot pressure center track

In general, left foot COP is more lateral while right foot COP is more medial. The left foot is larger in value than the right foot in both X- and Y-axis, which shows that the left foot works as the active foot and are more inclined to exert force from the outside while the right foot more tending to land at the heel [15]. At the stance phase the foot COP is at outer side of mid-foot, then moving downward and inward, reaching a pressure peak at the heel and a 2nd peak at the forefoot.

Pressure Integral Distribution of Partitions in the Plantar

Partitions in the plantar have different functions. The Pressure-Time Integral (impulse) of each reflects its contribution rate to the speed. Figure 5 shows the pressure integral (PTI) distribution of 10 partitions in the plantar.

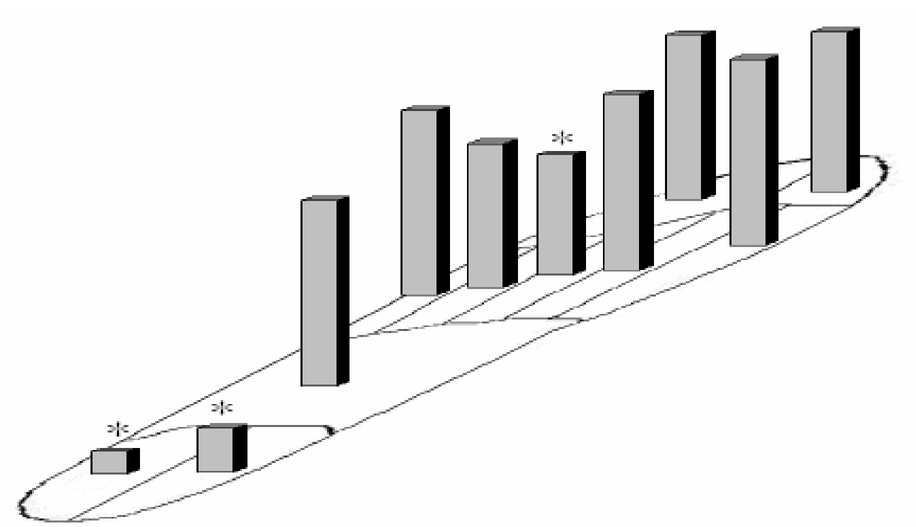


Figure 5. The pressure integral (PTI) distribution of 10 partitions in the plantar

As shown in the figure, distribution of Pressure-Time Integral is higher at the forefoot and toes, meaning most of the stance is finished at the forefoot in mid-long running. In contrast, contact time between heel and the ground is short, and the pressure between the two is relatively smaller.

Pressure peak is an important index reflecting the pressure distribution in the plantar. Its value is of important impact to foot fatigue accumulate and sport injury [16]. From figure above it can seen that pressure is the highest at M5 and M3 area, where overfatigue may cause arch collapse at the forefoot. Because distribution of pressure peak and impulse is similar in characteristic, forefoot is the main area of load and force drive during mid-long running as the test data shows.

Pressure Peak (PP) Distribution of 8 Points in the Plantar in Mid-Long Running

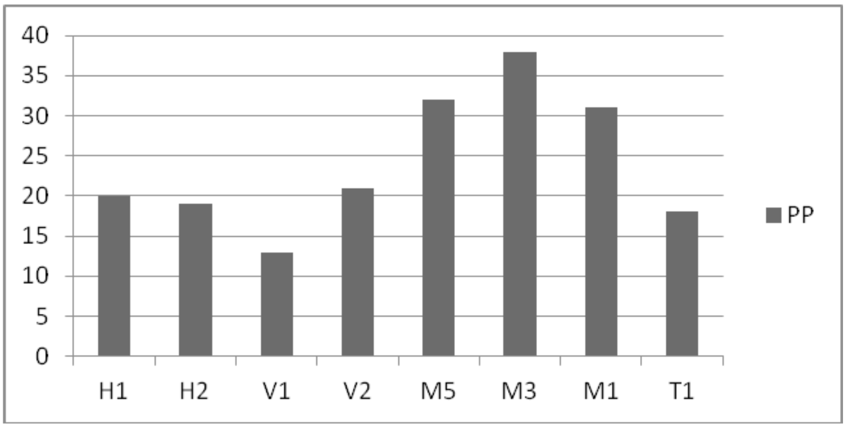


Figure 6. The distribution of pressure peak of plantar in mid-long run

Experiment Result Analysis

Step Size, Step Frequency, and Step Speed

Step Size is composed of touchdown distance, leg drive distance, support distance during the stance period. From experiment data we can know that the step size decreases successively from master, level 1 to level 2. In mid-long running step size is in an approximately linear relationship with speed. At specific speed, motor individuals will run with specific step frequency and size while step frequency is independent with the speed.

Distribution of Pressure in the Plantar

Pressure in the plantar is different in motion from that in rest. During middle-distance running distribution of pressure in the plantar at the forefoot can be divided into 4 categories: medial, mid-medial, central, mid-lateral. It is commonly acknowledged that sportsman should land with foot flat as mid-long running is a kind of endurable sport. However, research of this article has found that some mid-long runners land on forefoot while some others land on arch, with no heel strikers found. For those landing on arch, the landing COP is at mid-lateral foot with larger hitting force peak. For those landing on forefoot, the landing COP is at the 5th metatarsal bone of lateral forefoot with smaller hitting force peak and more flexible change in pressure.

The Relationship between Plantar Pressure and Sport Injury

Injury of mid-long running is mainly chronic with acute disease rarely seen. However, injury accumulate still deserves attention from athlete. Main reason of injury in middle-distance running includes: 1. landing at a wrong point of foot; 2. foot over-pronation; 3. landing with too big hitting force; 4. inconsistent stress between left and right foot.

CONCLUSION

This article uses RS-scan force test system to study characteristics of the foot gait and pressure distribution in mid-long running by selecting 14 mid-long running athletes as well as 8 ordinary teenagers and reaches below conclusion through analysis of test data:

(1) COP track is in a S-shape. Testees land on the outer side of midfoot while kick off at the middle forefoot. As active foot, left foot is different from the right foot because of its more lateral COP track.

(2) Impulse or PTI in the plantar is more centralized at forefoot, metatarsal bones as well as midfoot and the smallest at the heel. This indicates that the heel contributes the least to the running speed.

(3) Pressure Peak (PP) reaches the highest at the middle of forefoot, meaning this partition suffers the most from impulse load.

(4) Through comparative analysis of test data, during mid-long running forefoot is the main area with risk of sport injury and deserves more attention.

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THE INFLUENCE OF SODIUM CHLORIDE REPLACEMENT WITH POTASSIUM CHLORIDE AS A CURING AGENT ON THE QUALITY OF TANNED PUFFERFISH (*Arothon reticularis*) SKIN

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THE INFLUENCE OF SODIUM CHLORIDE REPLACEMENT WITH POTASSIUM CHLORIDE AS A CURING AGENT ON THE QUALITY OF TANNED PUFFERFISH (*Arothon reticularis*) SKIN

ABSTRACT. The pufferfish skin is a by-product that is underutilized. Skin tanning is the prospect way to enhance the economic value of pufferfish skin. The tanning process is a long one, including the process of curing the skin. Sodium chloride is commonly used for curing the skin. However, sodium chloride can increase the total dissolved solids (TDS) that will be problematic in the environment. Potassium chloride can be used instead of sodium chloride. This study aims to determine the influence of substituting sodium chloride with potassium chloride on the quality of tanned pufferfish skin. Sodium chloride and potassium chloride were used in the skin curing process, while the storage time was 0, 1, 2, and 3 weeks. The assays performed are salt concentration on the skin, scanning electron microscope (SEM), FTIR, and physical quality of tanned pufferfish skin. The results showed that the salt content of potassium chloride in the skin was more easily absorbed than the salt of sodium chloride. The SEM and FTIR tests, descriptively, show no significant difference. The physical quality of the pufferfish skin preserved using potassium chloride is better than that of sodium chloride. Potassium chloride deserves to be used as a substitute for sodium chloride.
KEYWORDS: pufferfish, skin curing, salt, sodium chloride, potassium chloride

INFLUENŢA ÎNLOCUIRII CLORURII DE SODIU CU CLORURA DE POTASIU CA AGENT DE CONSERVARE ASUPRA CALITĂŢII PIELII DE PEŞTE-BALON (*Arothon reticularis*)

REZUMAT. Pielea de peşte-balon este un produs secundar insuficient utilizat. Tăbăcirea pielii este modalitatea de a creşte valoarea economică a pielii de peşte-balon. Procesul de tăbăcire este îndelungat şi include procesul de conservare a pielii. Clorura de sodiu este utilizată în mod obişnuit pentru conservarea pielii. Cu toate acestea, clorura de sodiu poate creşte cantitatea de solide totale dizolvate (TDS), care este problematică pentru mediul înconjurător. Clorura de potasiu poate fi utilizată în locul clorurii de sodiu. Acest studiu are ca scop determinarea influenţei înlocuirii clorurii de sodiu cu clorura de potasiu asupra calităţii pielii tăbăcite de peşte-balon. În procesul de conservare s-au utilizat clorura de sodiu şi clorura de potasiu, iar timpul de depozitare a fost de 0, 1, 2 şi 3 săptămâni. S-au efectuat teste precum concentraţia de sare din piele, microscopia electronică de scanare (SEM), FTIR şi calitatea fizică a pielii tăbăcite de peşte-balon. Rezultatele au arătat că conţinutul de sare al clorurii de potasiu din piele a fost mai uşor absorbit decât sarea din clorura de sodiu. Testele SEM şi FTIR, din punct de vedere descriptiv, nu prezintă nicio diferenţă semnificativă. Calitatea fizică a pielii de peşte-balon conservată utilizând clorura de potasiu este mai bună decât cea conservată utilizând clorura de sodiu. Clorura de potasiu merită să fie utilizată ca înlocuitor pentru clorura de sodiu.
CUVINTE CHEIE: peşte-balon, conservarea pielii, sare, clorură de sodiu, clorură de potasiu

L'INFLUENCE DU REMPLACEMENT DU CHLORURE DE SODIUM PAR LE CHLORURE DE POTASSIUM COMME AGENT DE CONSERVATION SUR LA QUALITÉ DU CUIR DE POISSON-GLOBE (*Arothon reticularis*)

RÉSUMÉ. Le poisson-globe est un sous-produit insuffisamment utilisé. Le tannage de la peau est le moyen d'augmenter la valeur économique de la peau du poisson-globe. Le processus de tannage est long et comprend le processus de conservation de la peau. Le chlorure de sodium est couramment utilisé pour la conservation de la peau. Cependant, le chlorure de sodium peut augmenter la quantité de solides dissous totaux (TDS), ce qui est problématique pour l'environnement. Le chlorure de potassium peut être utilisé à la place du chlorure de sodium. Cette étude vise à déterminer l'influence du remplacement du chlorure de sodium par le chlorure de potassium sur la qualité du cuir de poisson-globe. Le chlorure de sodium et le chlorure de potassium ont été utilisés dans le processus de conservation et le temps de stockage a été de 0, 1, 2 et 3 semaines. On a effectué de tests comme la concentration de sel de la peau, la microscopie électronique à balayage (MEB), le FTIR et la qualité physique du cuir du poisson-globe. Les résultats ont montré que la teneur en sel du chlorure de potassium dans la peau a été plus facilement absorbée que le sel de chlorure de sodium. Les tests MEB et FTIR, du point de vue descriptif, ne montrent aucune différence significative. La qualité physique de la peau de poisson-globe conservée en utilisant du chlorure de potassium est meilleure que celle préservée en utilisant du chlorure de sodium. Le chlorure de potassium mérite d'être utilisé comme substitut du chlorure de sodium.
MOTS-CLÉS: poisson-globe, conservation de la peau, sel, chlorure de sodium, chlorure de potassium

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INTRODUCTION

Pufferfish is a kind of fish that is classified in fish that cannot be used in the process of fishing in the sea. During this time the pufferfish is just thrown away and becomes beach and sea waste. Pufferfish is a unique fish because it has a round body shape, attractive color and has small spines on the surface of the skin [1]. Küçükakin *et al.* [2] also stated that fish skins have gained an increased interest in the leather industry for producing leathers with attractive and unique grain structure, due to their high potential as an additional raw material source of leather industry.

Generally, all types of fish skins from aquatic environments can be tanned even though in practice only a few fish species can produce skin that is soft, radiant, has good scales and can be produced into leather and shoes [3]. The need for leather as a fashion ingredient increases every year, whereas raw material for tanning is increasingly limited. Tanning the pufferfish skin can be an alternative to the problem.

The tannery process consists of a long stage and begins with skin curing. Skin curing is one of the important processes in a tannery because, with curing, skin quality can be maintained. Skin is an organic material that is resistant to the external environment, both chemically and biologically. Skin can be damaged due to the presence of proteolytic enzymes produced by bacteria or fungi. Proteolytic enzyme can degrade the protein in the skin and remove dead tissue. Following the broken tissue of the animal, these bacteria cause autolysis (self hydrolysis) of the collagen. This breaks down the protein to amino acids, which further break down to produce ammonia [4].

Sodium chloride salt is a chemical commonly used in the process of curing the skin. In the context of clean technology, it is useful to calculate the amount of salt used in the tannery globally. Physically, salt is a crystal-shaped white solid object that is a collection of compounds with the largest part of sodium chloride (>80%) and other compounds such as magnesium chloride, magnesium sulphate, calcium chloride, and others [5] However, sodium chloride discharged in the soak liquor due to salt curing methods forms the largest component of most tanning effluents in terms of contribution to dissolved solids and chlorides in the effluents. Sodium chloride is the most difficult to treat and hence poses difficulties in the effluent treatment. They contribute in large measure to total dissolved solids (TDS) and to chlorides in the composite tannery effluent [6]. Sarker *et al*. [7] also state that this conventional technique is very popular due to the availability of common salt (sodium chloride) and its cost-effective procedure but it generates a huge pollution problem increasing salinity. As a result, an alternative method of using less or no salt for hide curing needs to be developed.

Another type of salt used for skin curing is potassium chloride [8]. Bailey and Gosselin [9] reported that curing animal hides and skins with potassium chloride in place of common salt has been carried out with steer hide by brine curing method. Potassium chloride is an almost perfect copy of sodium chloride curing without the environmental consequences associated with sodium chloride. Therefore, the substitution of sodium chloride with sodium chloride as a curing agent is worthy of further study.

EXPERIMENTAL

Materials

The materials of this research were 8 pieces of pufferfish skin obtained from traditional fish market in the District of Rembang (East Java, Indonesia), salts (sodium chloride and potassium chloride), distilled water, and chemicals for histological assay, Scanning Electon Microscope (SEM), Fourier Transmitted Infra Red (FTIR), and physical quality assay. The tools were blades, buckets, Baume meter, Becker glass, mixer, electric stove, incubator, scissors, and paper filter.

Methods

Leather Treatment

After cleaning the remaining grease, blood, meat, and dirt, fresh skin was then soaked in saturated salt at the high level of salt concentrations (salinity) 20-24°Be. Concentrations of salt should not be under 20ºBe. The salinity levels were measured with an instrument called Baume meter. The pufferfish skin were soaked in various salts (sodium chloride and potassium chloride) and curing time (0, 1, 2, and 3 weeks). The cured skin samples were collected every week.

Determination of Sodium Chloride Concentration

Chloride concentration was determined by classical Mohr [10] titration. Residual brine samples were diluted (1:100 v/v) in nano-pure water prior to titration. All samples were run in triplicate.

Physical Testing of Leather Samples

The samples for physical testing were obtained as per IULTCS methods [11]. The samples were conditioned at 80.4°F (27°C) and 65.2 % R.H. for 48 hrs. Physical properties such as tensile strength and percentage of elongation were investigated as per standard procedures. Each value reported is an average of four (2 along the backbone, 2 across the backbone) measurements.

Analysis of Functional Group Using FTIR Spectrophotometer

Analysis of functional group using Perkin Elmer FTIR (Chicago, USA) equipped with universal Attenuated Total Reflectance (ATR) diamond/ZnSe crystal at room temperature. Tanned pufferfish skin FTIR spectra were in the 500-4000 per cm range and collected in four scans with automatic signal gain control at a resolution of 16 per cm against a background spectrum recorded from a clean, empty cell. FTIR was conducted with a mid_IR deuterated triglycine sulfate detector and optical KBr beam splitter.

Determination of Morphology

Analysis of the tanned pufferfish skin morphology was observed by Scanning Electron Microscope (SEM) type JEOL JSM-5310 LV at 4000 times magnification for a flat cross-sectional area.

Data Analysis

The data of sodium chloride and potassium chloride concentration, tensile strength, and percentage of elongation were described as the Mean±SD. Data were analyzed using 2x4 factorial analysis. Especially for data of sodium chloride and potassium chloride concentration in pufferfish skin were also analyzed using one way ANOVA analysis. Then followed by Duncan's multiple-range test (DMRT) using software SPSS Inc., (Chicago, IL, USA). Differences considered significant when the probability was less than 5%. Another data were conducted with descriptive method.

RESULTS AND DISCUSSIONS

Sodium Chloride Concentration

The concentration of sodium chloride and potassium chloride in pufferfish skin was showed in Table 1. Based on the results, the longer curing time by salting the higher salt concentration in the skin. It indicates that skin takes time to fully absorb the sodium chloride in the salt. It makes the skin more resistant to decay that was caused by microorganisms, so the quality of fresh skin will be maintained [5]. Strumylaitė *et al*. [12] also state that the effects of salt as a curing agent is a high osmotic property so as to solve the microbial cell membranes. When microorganisms are placed in a concentrated salt solution (30-40%), the water in the cells would be out by osmosis and the cells undergo plasmolysis and will be hampered in breeding. However, based on the statistic analysis, potassium chloride can be absorbed by skin significantly ($P<0.05$) quicker than sodium chloride. Curing by potassium chloride significantly increases the potassium chloride concentration in skin every week, while curing by sodium chloride increases the sodium chloride concentration after 3 weeks.

Table 1: Sodium chloride and potassium chloride concentration in Pufferfish skin (%)

Type of salt	Curing time (week)				Mean*
	0	1	2	3	
Sodium chloride	47.20±0.5	51.79±1.9	50.45±0.4	54.07±3.5	50.88±3.0
Potassium chloride	45.56±0.5	60.30±1.1	63.01±0.8	91.79±0.2	65.17±35.8
Mean	46.38±1.0^{x}	56.04±4.9^{y}	56.73±7.3^{y}	71.93±21.9.7^{z}	

Results are given as mean ± standard deviation
^{xyz}Different letters within the same row indicate statistical significance at p<0.05 level

Pickling salt is a major contributor to pollution of salt by tannery plant, so a substitute friendlier for the environment must be sought to cure skin. Wu *et al*. [13] have examined the replacement of sodium chloride with potassium chloride with the result that the skin is cured with potassium chloride, and the resulting tanned skin has the same quality as that cured with sodium chloride. Potassium chloride can be used as an alternative curing salt (sodium chloride). This salt is safe to use as a curing agent and the effluent does not harm plants, but is actually beneficial to plants as a nutrient.

SEM Analysis

The skin surface was analyzed using SEM. Images are taken to analyze the morphology of the skin surface of tanned pufferfish skin. It is observed from the skin surface that collagen fibers braided compactly into each other forming a matrix. Spines are fixed firmly between the weave [13]. The projection of the spiny ends can be seen from Figures 1 and 2. The longer time of curing skin the more damaged the structure of the skin, resulting in a weak spinal shape. In SEM images of skin cured with sodium chloride and potassium chloride, it can be observed that there was a difference in the shape of the spine in the 3rd week of curing. Wibowo *et al*. [1] state that the spine of the pufferfish consists of collagen protein shrouded by keratin. Skin damage is thought to be due to the presence of microorganisms such as collagenolytic and keratinolytic bacteria that begin to grow on the skin surface during the second week so that the enzymes produced by bacteria degrade collagen and keratin proteins [5].

Curing using sodium chloride can maintain the outer surface of the spine erect until the first week, but in the second week the spine is no longer erect and looks brittle the following week, but the outer shape of the spinal can still be clearly seen. It is almost the same process of skin curing as when using potassium chloride, but by

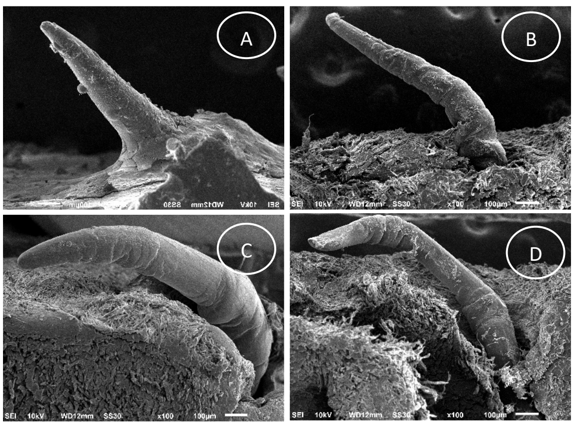

Figure 1. Scanning Electron Microscope (SEM) images of pufferfish skin preserved by sodium chloride in various weeks. A: 0 week; B: 1 weeks; C: 2 weeks, D: 3 weeks.

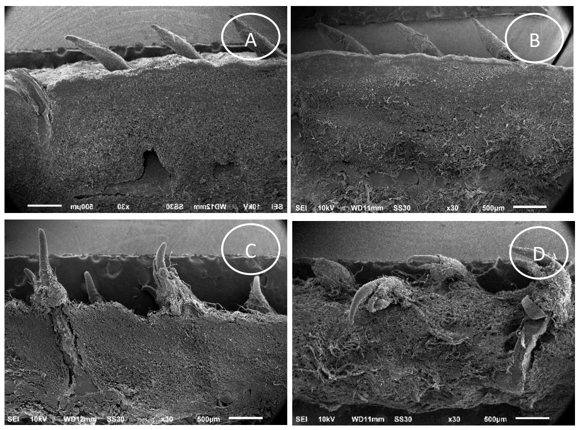

Figure 2. Scanning Electron Microscope (SEM) images of pufferfish skin preserved by potassium chloride in various weeks. A: 0 week; B: 1 week; C: 2 weeks, D: 3 weeks.

the third week, the spinal form looked damaged. According to Wu *et al*. [14], sodium chloride has similar physical and chemical properties to potassium chloride but is very much different in one respect. While sodium chloride has negative effects on the growth of microorganisms when applied to the soil, potassium chloride is a fertilizer that encourages plant growth and does not result in the environment problems that are associated with saturated brine.

FTIR Analysis

The absorption at wavelength 650-4000 cm^{-1} were investigated and was showed in Figures 3 and 4. This qualitative analysis showed that all the spectra of the leather samples were almost the same. This is because leather is made up of protein which is collagen, the major protein from which skin is formed [15]. The spectra display a broad band in the range 3650–3000 cm^{-1} that belongs to the stretching vibrations of the coordinated water molecules [16]. The band located at 1627–1647 cm^{-1} may be assigned to the vibrations of the -OH groups coordinated at the Cr(III) cation [17].

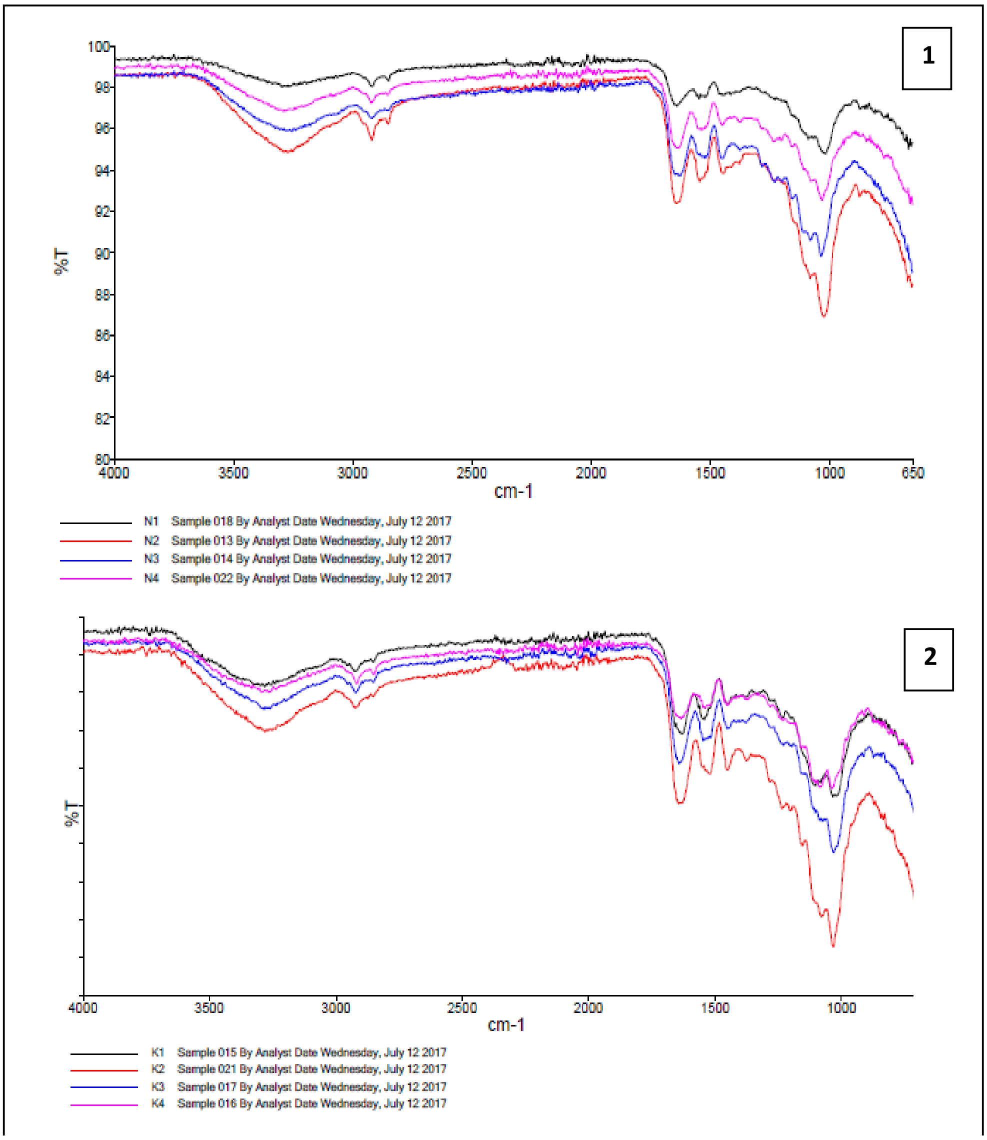

Figure 3. 1: Results of FTIR of tanned pufferfish skin by sodium chloride in various weeks; 2: Results of FTIR of preserved pufferfish skin by potassium chloride in various weeks; N1: 0 week; N2: 1 weeks, N3: 2 weeks; N4: 3 weeks. K1: 0 week; K2: 1 weeks, K3: 2 weeks; K4: 3 weeks

Table 2 shows the tensile strength of the tanned pufferfish skin. From this table, it can be observed that the tanned skins cured by potassium chloride have significantly better tensile strength (P>0.05) than tanned skins cured by sodium chloride. On the other hand, curing time did not effect to tensile strength of tanned pufferfish skin. Strength values are agreeable in comparison with upper leathers [13]. However, Table 3 shows the significant effect of curing time of pufferfish skin (P<0.05) on the percentage of elongation of tanned pufferfish skin, while the type of curing agent did not have much effect on the elongation of the tanned skin.

Table 2: Tensile strength of cured skin (kg/cm^2)

Type of salt	Curing time (week)				Mean*
	0	1	2	3	
Sodium chloride	8.62±2.3	7.14±0.8	6.63±2.0	4.49±1.0	6.92±2.0^a
Potassium chloride	6.50±0.8	9.97±1.8	9.92±0.7	8.09±2.1	8.58±1.9^b
Mean^{ns}	7.56±1.9	8.56±1.9	8.27±2.2	6.89±2.5	

Results are given as mean ± standard deviation
^{ab}Different letters within the same row indicate statistical significance at p<0.05 level
NS means non significant difference at P>0.05 level

Table 3: Percentage of elongation of tanned pufferfish skin (%)

Type of salt	Curing time (week)				Mean^{ns}
	0	1	2	3	
Sodium chloride	25.98±11.5	32.41±0.1	47.46±0.4	49.56±0.2	38.85±11.5
Potassium chloride	33.76±1.7	34.87±3.6	37.99±2.96	41.01±2.4	36.91±3.7
Mean	29.87±8.1^x	33.64±2.5^x	42.72±5.7^y	45.29±5.1^y	

Results are given as mean ± standard deviation
^{xyz}Different letters within the same column indicate statistical significance at p<0.05 level
NS means non significant difference at P>0.05 level

It is the similar properties of the two salts that allow skins and hides to be soaked with potassium chloride in the same way as NaCl [18]. Bailey and Gosselin [16] proved that potassium chloride can be substituted for sodium chloride to produce brine cured hides. It can be done in paddles, raceways, processors or salt packs and in most respects will require almost no change in current brine curing facilities. They reported experimentally and commercially curing cattle hides, calfskins and pigskins with potassium chloride. The overall results suggest virtually no difference between the quality of hides and skins produced by this curing method compared to traditional curing with sodium chloride. However, at the same time, their research reported that the limited pressure on sodium chloride in packing house effluents precluded the use of this material for curing.

CONCLUSIONS

The quality of tanned pufferfish skin cured using potassium chloride is almost the same with that of skin cured using sodium chloride. Potassium chloride is worth using as a substitute for sodium chloride as a curing agent.

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IMPACT OF SPORT DANCING ON THE DYNAMICS CHARACTERISTIC OF FOOT MOVEMENT OF COLLEGE STUDENTS

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IMPACT OF SPORT DANCING ON THE DYNAMICS CHARACTERISTIC OF FOOT MOVEMENT OF COLLEGE STUDENTS

ABSTRACT. With the merits of improving physical quality, body shaping and physical aesthetics, sport dancing is more and more popular among college students. The gestural movement of sport dancing is mainly realized through the reaction of feet after contacting the ground, so it is necessary to scientifically analyze the influence of sport dancing on the dynamics characteristic of foot movement of college students. In this paper, the effect of sport dancing on the insole pressure intensity and gait characteristics of college students is studied by means of experimental test. First, relevant concepts were elaborated. In the experimental test, the foot pressure test system was adopted. And then analysis was made after the comparison between the experimental group and the control group. Finally, analysis and discussion of the experimental results were carried out. This paper is of great significance for evaluating the impact of sport dancing on the healthy development of college students' feet and guiding the force condition of the feet in sport dancing.

KEY WORDS: sport dancing, foot pressure test system, gait, insole pressure intensity, experimental test

IMPACTUL DANSULUI SPORTIV ASUPRA CARACTERISTICII DINAMICE A MIȘCĂRII PICIORULUI LA STUDENȚI UNIVERSITARI

REZUMAT. Având merite precum îmbunătățirea calității fizice, a formei corporale și a esteticii fizice, dansul sportiv este din ce în ce mai popular printre studenți. Mișcarea gestuală a dansului sportiv se realizează în principal prin reacția picioarelor după contactul cu solul, așadar este necesar să se analizeze științific influența dansului sportiv asupra caracteristicii dinamice a mișcării picioarelor studenților. În această lucrare se studiază efectul dansului sportiv asupra intensității presiunii branțului și caracteristicile de mers ale studenților prin intermediul unui test experimental. În primul rând, au fost elaborate concepte relevante. În cadrul testului experimental a fost adoptat sistemul de testare a presiunii piciorului. Apoi s-a efectuat o analiză în urma comparației dintre grupul experimental și grupul martor. În cele din urmă, s-au analizat și discutat rezultatele experimentale. Această lucrare are o mare importanță pentru evaluarea impactului dansului sportiv asupra dezvoltării sănătoase a picioarelor studenților și pentru direcționarea forței picioarelor în dansul sportiv.

CUVINTE CHEIE: dans sportiv, sistem de testare a presiunii piciorului, mers, intensitatea presiunii branțului, test experimental

L'IMPACT DE LA DANSE SPORTIVE SUR LA CARACTÉRISTIQUE DYNAMIQUE DU MOUVEMENT DU PIED AUX ÉTUDIANTS UNIVERSITAIRES

RÉSUMÉ. Ayant des mérites tels que l'amélioration de la qualité physique, la forme du corps et l'esthétique physique, la danse sportive est de plus en plus populaire parmi les étudiants. Le mouvement gestuel de la danse sportive est principalement réalisé par la réaction des pieds après le contact avec le sol, il est donc nécessaire d'analyser scientifiquement l'influence de la danse sportive sur la caractéristique dynamique du mouvement des pieds des élèves. Dans cet article, on étudie l'effet de la danse sportive sur l'intensité de la pression de la semelle intérieure et les caractéristiques de la marche des étudiants par un test expérimental. Tout d'abord, des concepts pertinents ont été développés. Dans le test expérimental, le système de test de pression du pied a été adopté. Une analyse a été faite suite à la comparaison entre le groupe expérimental et le groupe témoin. Finalement, les résultats expérimentaux ont été analysés et discutés. Ce travail est d'une grande importance pour l'évaluation de l'impact de la danse sportive sur le développement sain des pieds des étudiants et pour la direction de la force de la jambe dans la danse sportive.

MOTS CLÉS: danse sportive, système de test de pression du pied, démarche, intensité de la pression de la semelle intérieure, test expérimental

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INTRODUCTION

As a new sports program combining dancing and sports, sport dancing not only exercises the body, but also is of great appreciation value [1]. Currently, Latin dance and modern dance are included in the formal competition items of sports dance. Sport dancing is becoming more and more popular, because it has sport and artistic characteristics at the same time, integrates bodybuilding into physical and mental adjustment and is unrestricted by site, fitness equipment and age.

According to relevant investigation and analysis, sport dancing has a positive effect on the nervous system, cardiopulmonary system, constitution, physical quality, and body shape of humans. The college period is the critical period of physical growth. And the positive influence of sport dancing can improve the self-confidence of college students and exercise their minds. At present, more and more college students choose sport dancing courses in physical education [2].

In dance sport, the dance movements are finished through combining the acting force generated after the feet contact the ground and the body's coordinated control. The joints and parts of the body are exercised through muscle coordination throughout the body. But in the sports dance, the main stress position of the body is the foot. The sport dancing includes such actions as step touch, striding, hop step, etc. The dynamic characteristic of the foot movement of college students are influenced unconsciously in their sport dancing exercises. Combining with the modern foot pressure measurement system, and on the basis of elaborating on the theory of relevant foot characteristics, this paper takes five 2013 college students from the Sports Performance Art Department at a domestic physical culture institute as the test objects of the experimental group, and five sport dancing beginners as the test objects of the control group. The mathematical statistics of the plantar kinetics parameters were carried out when they are walking normally. After analyzing the plantar pressure distribution and gait characteristics, this paper probes into the impact of sport dancing on the dynamics characteristic of foot movement of college students. This paper provides theoretical guidance for promoting the popularization of sports dance.

OVERVIEW OF RELEVANT THEORIES ON THE DYNAMICS OF HUMAN FOOT MOVEMENT

Foot Bones

Foot is one of the important organs of human bodies. The bones of foot are composed of 7 tarsals, 5 metatarsals and 14 phalanxes, which constitute a rigid entity [3]. Together with the muscles of the foot, these bones form an important part of human body, which play the role of weight bearing, buffering, absorbing impact, and maintaining body balance. Figure 1 shows the distribution of the foot skeleton.

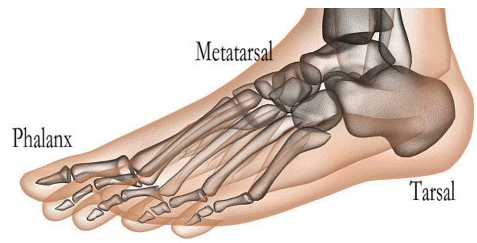

Figure 1. Foot skeleton distribution diagram

As shown in Figure 1, the foot bones and muscles form a flexible and rigid entity. The intensity of pressure between the foot and the ground is 1.5 to 10 times of the body weight in different movements. Therefore, studying the dynamic characteristics of foot movement is a prerequisite to understand and protect the foot and also a guarantee for the healthy development of the foot of college students [4].

Foot Gait Characteristics and Pressure

Foot Gait

The posture of a person when he/she walks naturally is called the "gait". It is the external manifestation of the human foot's structure, function and the movement regulating system, and can reflect the function, spirit and the mentality of the human body [5].

Current gait measurement methods include image measurement, measurement of the reaction force of the support force, EMG measurement, etc. The biomechanical study of gait refers to applied research of the test, analysis and evaluation of the function and state of human walking using biomechanical methods and techniques and based on the basic theory of human anatomy and physiology [6]. Generally, the cycle, step size, step frequency, and time phase are the key parameters to study the gait. This paper takes gait as a major feature to reflect the dynamics of the foot movement of college students engaged in sports dancing.

Foot Pressure

Foot pressure is the main research area of foot movement mechanics. Foot pressure is divided into static pressure and dynamic pressure. Static pressure refers to the foot pressure distribution when the foot is standing statically, and the dynamic pressure refers to the situation of the foot pressure distribution changing over time when the body is engaged in different movements [7]. The size of the healthy foot pressure is affected by the weight, age, and daily physical activity. The application research of foot pressure has extended to medical physiotherapy and rehabilitation, sports military training, industrial shoemaking, and so on [8].

According to the sense judgement, the foot heel bears the maximum pressure, which is followed by the metatarsal bones. The toes bear the smallest pressure. With the development of computer technology, and combining with mechanics, geometry and other knowledge, more and more foot measurement technology can accurately measure the foot pressure. The application of these measurement techniques to the study of the foot dynamic characteristics provides a reliable measurement tool for theoretical researches and also provides guarantee for the practical applications [9].

EXPERIMENT DESIGN

Experiment Object

Table 1: The basic information of test group and control group

Test group						
Item	Gender	Height	Weight	Shoe size	Training years	Insole size
1	Female	160.5	41	35	3	35/36
2	Female	161.1	48.5	36	4	35/36
3	Female	163.4	49	35	3	35/36
4	Female	164	46	36	3	35/36
5	Female	167	63.4	37	4	37/38
Control group						
6	Female	162	58	37	1	37/38
7	Female	163	45.1	37	2	37/38
8	Female	163	45.7	37	1	37/38
9	Female	162	48.1	36	1	37/38
10	Female	165	47.1	37	1	37/38

This paper takes five girl students from a sports art class at a domestic physical culture institute as the test subjects of the experimental group, and five students without sport dancing basis as the test subjects of the control group [10]. Their basic information is shown in Table 1.

Test Equipment

In this study, the insole pressure measuring system produced by Medilogic of Germany was adopted. The insole has 64 FSR pressure sensors. The pressure range tested was 0.5~65N/cm^2 and the sampling frequency reached 350Hz [11].

Test Process Design

The test is arranged in the school gymnasium. During the test, 10 students in the test group and the control group were asked to walk at a normal speed and with normal postures and ensure that the insoles match their shoe sizes and that the insoles were not folded to guarantee the accuracy of the data. Specific test procedures are as follows:

(1) Collect the basic information of testees based on Table 1

(2) Warm-up of the testees and learn the attentions

(3) Instrument installation and debugging

(4) Test data recording and filing

(5) Instrument removal and checking the insole condition

Observe the students' situation during the test and ensure that the instrument is in normal working condition and operating condition. Figure 2 shows the situation of the female testees with the instrument put on their body.

Figure 2. The test situation of the student with insole pressure test device

Data Statistics and Test Indicators

Data statistical Method

SPSS11.5 statistical analysis package is adopted for mathematical statistics and T detection was applied to complete the analysis of various variables [12]. The statistical significance level á=0.05.

Test Indicators

In order to analyze the gait and insole pressure intensity, this paper selects relevant indicators to carry out measurement and analysis. The main names and descriptions are shown in Table 2 [13].

Table 2: The description of test indicator

Name	Description
Impulse	The pressure-time integral of each partition
Average pressure	Average pressure of characteristic area
Max pressure	Max pressure of characteristic area
Foot axis	The connection of midpoint Heel with the second metatarsal

In this paper, the pressure insole area is divided mainly into such three parts as forefoot, midfoot and heel. And great thumb (GT), medial metatarsal (MM), middle metatarsal bones (MidMM), lateral metatarsal (LM) and heel (Heel) were studied mainly.

RESULTS AND DISCUSSION

Gait Features Analysis

First, the walking speed, step size, duration, and ground contact area of the test group and the control group are collected. The gait statistic data of ten sport dancing students are shown in Table 3.

Table 3: The gait test data

Item	Speed	Step size	Relative step	Lasting time	Contact area
1	4.9	1.46	0.91	1.05	18.5
2	6.9	2.01	1.25	1.04	20.0
3	5.5	1.53	0.94	1.03	17.0
4	4.0	1.18	0.72	1.05	20.0
5	5.7	1.70	1.01	1.06	22.5
6	4.1	1.15	0.71	0.99	21.0
7	4.1	1.19	0.73	1.04	20.5
8	4.4	1.45	0.89	1.08	19.0
9	5.0	1.34	0.83	1.03	20.0
10	4.6	1.41	0.86	1.02	15.0

Human walking speed is the main characteristic of gait measurement. If the speed significantly slowed down, it indicated that the foot may have pathological signals. When the foot contacts with the ground for a long period, the foot is easy to fatigue and is in a sub-health state. It can be seen from Table 3 that there was no significant difference between the test group and the control group in terms of walking speed, foot contact area and other data [14]. However, the values of walking speed and contact area of the test group were greater than those in the control group, and the contact time with the ground was less than that of the control group, indicating that the testees who have long been engaged in sport dancing training have relatively healthier foot [15]. The strict regulations and requirement on steps, posture, balance and stability, movement and rhythm of sport dancing promote the healthy development of the gait features of the foot.

Table 4 and Table 5 are the test data of the standing duration, effective foot length and stride width of the left foot and right foot in the test group and control group.

Table 4: The test data of left foot

	The stand up last time	Foot length	Stride width
Test group (N=5)	61.00±1.06	46.12±17.27	4.92±0.95
Control group (N=6)	60.08±0.66	64.75±8.62	6.05±1.85
T value	1.753	-2.333*	-1.23

Table 5: The test data of right foot

	The stand up last time	Foot length	Stride width
Test group (N=5)	58.60±1.08	46.12±17.27	4.92±0.95
Control group (N=6)	59.33±2.56	64.75±8.62	6.05±1.85
T value	-0.593	-2.511*	-0.304

* signifies that the results have significant differences. P<0.05

It can be seen from the table that there is a significant difference in the effective foot length between the test group and the control group. The decrease in foot length indicates that through sport dancing, the contact area between the foot of students in the test group and the ground has reduced, relative foot length reduced, and the endurance of the bones and muscles of the foot improve somewhat compared with those of the control group [16].

Table 6: Relative standard deviations of the dispersion of insole pressure in a single step of different groups (%)

	Time interval	Left support period	Right support period
Test group (N=5)	4.44±2.12	6.48±± 2.13	7.90±3.66
Control group (N=6)	5.03±2.61	5.57±2.09	5.50±4.12
T value	-0.603	0.716	1.019

Then, the stability of the foot of the testees was analyzed. The time interval between the two steps was measured and the left and right support period was obtained. And then, the distribution of the insole pressure in a single step of the testee was obtained. Table 6 shows the relative standard deviations of the dispersion of insole pressure in a single step of different groups.

It can be seen from the table that although there was no significant difference between the test group and the control group, the time interval of the test group was shorter than that of the control group, and the supporting time of both the left foot and right foot is longer than that of the control group. The results show that there is less insole pressure dispersion in a single step, and that the foot gait is more stable, which further suggests sport dancing has a positive effect on the improvement of college students' foot gait stability.

Distribution of Insole Pressure Intensity

Analysis of Maldistribution of the Left and Right Foot Pressure

From the perspective of biomechanics and motion dynamics, there is a slight difference between the left foot and right foot of humans in terms of structure, toughness, and strength. In the test result, the distribution of the insole pressure intensity of the left and right foot is simulated in the form of 3D image, as shown in Figure 3.

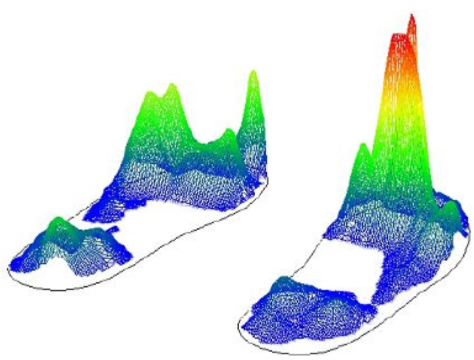

Figure 3. The 3D diagram of insole pressure intensity of the testees' left and right foot in the course of walking

As shown in the picture, the intensity of pressure in the hallux of the right foot is obviously larger than that of the left foot, while the heel of left foot carries larger pressure than the heel of the right foot, suggesting different exercise habits of testees result in differences in the distribution of bipedal pressure. The objective simulation data provided by the foot pressure system is conducive to improving the foot movement habits and can prevent the injuries of skeletons, muscles and joints caused by the continuous uneven pressure distribution.

Plantar Impulse and Foot Gravity Distribution

The plantar impulse is the buffering ability of all areas of the foot to the acting force between the human bodies and the ground. The integral of the pressure of each area and the time is the impulse. The medial metatarsal area has the largest impulse and the heel has the minimum impulse in the test group. In the control group, the maximum impulse is shown in the heel, and the largest load is in the first and second metatarsal bones.

The foot pressure test system can track the change of the gravity center of the foot of the test group and the control group. The study of the changes in human body gravity is also helpful to evaluate the impact of sport dancing on human foot.

The experimental results indicate that the dispersion degree of the gravity center track of the left and right foot is relatively small in the test group and the connecting lines of the pressure distribution vertical lines of the left and right foot are basically overlapping, while there is little overlap in the gravity center tracks in the control group and the dispersion degree of the tracks is large. The gravity tracks present a brokening trend. The result is that sport dancing is a kind of sport which is very demanding in terms of body balance. For college students in the test group, through the exercise of sport dancing, their physical power can be evenly distributed in the left and right foot, which can better reduce the load bearing and damage to the foot.

Distribution of Average Insole Pressure Intensity

Next, based on the foot partitions in the experimental design, the distribution of average insole pressure intensity of the college students in the test group and control group was collected. Since the left foot is the main pressure-bearing foot, the statistical data of the left foot are taken.

Table 7: The mean value of the insole pressure intensity in the test area of the test and control group (N/cm^2)

Code	GT	MM	MidMM	LM	Heel
1(L)	7.5	12.61	4.86	3.59	5.12
2(L)	12.1	10.34	5.12	4.86	7.21
3(L)	4.71	8.32	6.62	4.67	4.5
4(L)	6.94	5.61	8.45	7.42	5.03
5(L)	5.54	7.61	5.44	7.42	5.51
6(L)	9.28	5.77	9.02	6.55	10.82
7(L)	16.09	7.11	8.76	5.19	6.71
8(L)	10.51	6.52	8.33	4.7	8.61
9(L)	7.25	5.6	10.80	6.61	8.71
10(L)	15.10	9.0	8.87	7.77	8.31

It can be seen from the table that the maximum average pressure of the experimental group is shown in the hallux region, and the minimum value appears in the heel region. There was a significant difference between the means of pressure in the middle metatarsal region and the hallux region of the left foot ($P < 0.05$).

Distribution of Peak Value of the Insole Pressure Intensity

Table 8 shows the peak values of the insole pressure intensity of each area of the left and right foot of college students in the test group and control group.

It can be seen from the table that there is significant difference in the the peak values of the pressure intensity of heel region in the left foot and right foot in the test group and control group. The statistical data show that the maximum pressure intensity is shown in the medial metatarsal and middle metatarsal. They shall be protected specially in daily walking.

Table 8: The maximum value of the insole pressure intensity in each region of the left and right foot

Code	GT	MM	MidMM	LM	Heel
Test group(L)	26.35± D_	35.18± __	25.44± D	23.44± D	20.4±± D
Control(L)	39.35±± D_	37.18± D_	45.44± _	38.44± D	38.4± D
T value	-1.401	-0.316	-4.191*	-1.81	-4.979**
Test group(R)	41.35± __	48.18± D_	39.44± __	18.44±9.59	13.4± D
Control(R)	41.05± D_	45.6± D_	38.78± _	23.24± D	22.94±DD
T value	0.002	0.323	0.091	0.880	-2.556**

Comprehensive Analysis

Since sport dancing invloves standing, running, jumping and other basic movements in the exercise and competition, the foot is exercised for a long period of time. In addition, sport dancing is demanding for postures and arts, which promotes the steadiness and artistry of the dancer's gait.

Since there are significant differences between the experimental group and the control group in terms of engaging time and technical understanding degree, there are significant differences in the distribution features of pressure and the distribution of pressure. The gravity center distribution of the test group is more uniform and the foot impulse is larger. It is learned from the average pressure intensity value and the average pressure intensity distribution value that there is significant difference in the heel and middle metatarsal areas of the foot of test group and control group, which is related to the fact that the partial areas in the foot bear large pressure for a long time during sport dancing. As the main driving source of foot movement, the pressure intensity distribution in the toe area of the experimental group is greater than that of the control group, so that the body can perform difficult dance movements and maintain the balance of the body.

CONCLUSIONS

Sport dancing is more and more popular among college students. It is an inevitable trend to scientifically and objectively analyze the influence of sport dancing on the dynamics characteristic of foot movement of college students. In this paper, relevant foot theories were elaborated first, and then the test design process was introduced. The foot pressure test system was adopted to test the data of the test group and the control group and mathematical statistics and analysis were carried out. This paper is instructive in the following aspects:

1. Sport dancing plays an important role in the gait stability of the foot, and plays a positive role in the key parameters affecting gait.

2. There are some differences in

the pressure intensity data between the experimental group and the control group, and long-term sport dancing had a significant effect on the motion dynamics of the foot movement. On the one hand, sport dancing personnel shall carry out protection to the part bearing large pressure according to relevant test data; on the other hand, the beginners of sport dancing should train the toe area specifically.

3. Sports dancing has a positive effect on the healthy growth of the foot of young college students.

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OPTIMIZATION OF BOVINE LEATHER SOAKING PROCESS

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OPTIMIZATION OF BOVINE LEATHER SOAKING PROCESS

ABSTRACT. High quantities of water, chemical reagents and time are needed in leather processes which result in a huge investment for the tanning industry, therefore it is necessary to optimize it. Soaking is the first stage of leather process, responsible for cleaning and re-hydrating the skin through an aqueous bath. In this work, to study an ecological approach of the soaking step, two different types of soaking were evaluated comparing the traditional method against an enzymatic method. Bactericide, a wetting agent, a degreaser and enzymes were applied on the skins with two ways of preservation, salted skin and green skin. The pH value, conductivity and hide weight were determined to evaluate the process. The enzymatic method showed a better soaking performance giving good indications for an ecological approach of the soaking process.

KEY WORDS: green skin, leather process, salted skin, soaking

OPTIMIZAREA PROCESULUI DE ÎNMUIERE A PIELII BOVINE

REZUMAT. În procesul de fabricare a pielii sunt necesare cantități mari de apă, reactivi chimici și timp, care au ca rezultat o investiție mare pentru industria de pielărie, prin urmare este necesară optimizarea acestui proces. Înmuierea este prima etapă a prelucrării pielii, fiind responsabilă pentru curățarea și re-hidratarea pielii într-o baie de apă. În această lucrare, pentru a studia o abordare ecologică a operației de înmuiere, s-au evaluat două tipuri diferite de înmuiere, comparând metoda tradițională cu o metodă enzimatică. S-au aplicat bactericid, un agent de umectare, un degresant și enzime pe pieile conservate în două moduri, prin sărare și ecologic. S-au determinat valoarea pH-ului, conductivitatea și greutatea pielii pentru a evalua procesul. Metoda enzimatică a demonstrat o performanță mai bună la înmuiere, oferind indicaţii bune pentru o abordare ecologică a procesului de înmuiere.

CUVINTE CHEIE: piele crudă, prelucrarea pielii, piele sărată, înmuiere

L'OPTIMISATION DU PROCÉDÉ DE TREMPAGE DE LA PEAU BOVINE

RÉSUMÉ. De grandes quantités d'eau, de réactifs chimiques et de temps sont nécessaires dans le processus de fabrication de la peau, ce qui entraîne un investissement important dans l'industrie du cuir, raison pour laquelle il est nécessaire d'optimiser ce processus. Le trempage est la première étape du traitement de la peau, étant responsable du nettoyage et de la réhydratation de la peau dans un bain d'eau. Dans cet article, pour étudier une approche écologique de l'opération de trempage, deux types différents de trempage ont été évalués, en comparant la méthode traditionnelle avec une méthode enzymatique. Bactéricide, agents mouillants, dégraissants et enzymes ont été appliqués sur des peaux préservées de deux manières, salées et écologiques. La valeur du pH, la conductivité et le poids de la peau ont été déterminés pour évaluer le processus. La méthode enzymatique a démontré une meilleure performance de trempage, fournissant de bonnes indications pour une approche écologique du processus de trempage.

MOTS CLÉS : peau verte, traitement de la peau, peau salée, trempage

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INTRODUCTION

Leather industry is an important activity in many developing countries, which is dependent on the agro economy [1] and is responsible for the transformation of animal skin, a putrescible biological material in a stable and imputrescible product, the leather [2]. An important role in the tanning industry is the research focused on the improvement of the quality of leather ensuring a reduction of time, water and energy consumption, as well as of the pollution generated [3].

There are four major groups of sub-processes required to achieve finished leather: beamhouse operation, tanning, retanning and finishing processes [2].

Soaking is the first step of the beamhouse, which is a set of operations which constitute the first part of the tanning process. Soaking can be divided in two stages. The first soaking is used to make a first cleaning of the skin by removing a great amount of dirt and unwanted materials attached to it. Another objective of the first soaking is to increase the skin water content in order to reach more effectiveness in the subsequent cleaning [3]. In the second soaking, raw skins are treated with water and small quantities of imbibing substances, in order to hydrate the skin proteins and open the contracted fibers of the dried skins, solubilize the denatured proteins, eliminate the salt, used in the preservation step, and the residuals of blood, excrement and earth, attached to the skin [2].

Common soaking agents are alkali, sodium sulphide, salt and some surfactants. However, these materials often lead to environmental pollution.

In order to improve the technology, to facilitate skin soaking process, enzymes have been used as one of the most promising substitutes for traditional chemicals [4]. Protease and lipase enzymes seems to be quite promising as they can be efficiently used in the beamhouse operations of tanneries for leather manufacturing processes [5]. Some alkaline proteases are used to ensure faster absorption of water and to reduce the time required for skin soaking. A multi-enzyme system is often used in skin enzymatic treatment, because the multi-enzyme system would be more efficient through synergy effect of different enzymes [4]. However, many factors affect the enzymes in soaking process, such as enzymes ratios, enzymes loadings, presence of surfactants [6], enzymes species and some other additives [4]. In general, enzymatic activity in an aqueous medium, is strongly dependent on the pH values and salt factors such as concentration and species [7].

Other factor which can adversely influence the course of soaking and, consequently, the quality of leather, is the number and strains of microorganisms present in the aqueous medium, especially if they include proteolytic bacteria [8]. Another limited value is the dryness of the hide.

Soaking time and degree of diffusion of chemicals through the hide, achieved by drumming/paddle action are two more factors that influence the process [9].

In many cases, the soaking is performed in a drum because of the mechanical effect provided, assistance in accelerating the penetration of water and chemicals added in the float into the skin. However, there are some cases where the mechanical effect is not advisable, because it could damage the dried skin during the first soaking, causing excessive fiber breakage and even defects in the grain. To avoid this, the use of pits or paddles in the first soaking with little or without mechanical effect is an option [3].

In what concerns the process time, the longest the soaking time, 8-20 hours for wet salted hide or 24-48 hours for dried skins, the higher will be the putrefaction rate by bacterial action, which should be avoided with a careful procedure and addition of bactericides [9]. Not only could these effects be prevented by converting biological materials into a stable product, resistant to microbial activities but also the resistance to wet and dry heat is enhanced [10].

In this work, an enzymatic soaking was evaluated against a traditional soaking in order to improve more efficient and ecological soaking.

EXPERIMENTAL

Materials and Methods

Tests were performed with bovine skins, which had different steps of preservation, salted skin and green skin. Salted skin was provided by company Curtumes Aveneda and green skin was supplied by company Couro Azul.

The bactericide *Busan 85* and *Buzyme* enzymes were provided by the company *Buckmann* and the chemicals *Indiwet* were delivered by the company *Indinor*, a chemical company located in Portugal.

The soaking trials were performed in laboratory-scale tannery drums (LFA-9293, Mathis), with temperature and speed control. Other instruments included a Hach Conductivity/ TDS meter, Consort C562, Metrhom 691 pH Meter, Kern ALJ 220 – 4NM were used to analyze the soaking process.

Soaking Tests Methodology

Two different types of soaking were studied to compare the traditional method against the enzymatic method.

Soaking method was processed at 25 degrees and agitated with a little mechanical effect to avoid damaging the skin.

Samples of hide were first cleaned with 0.25% w/w sodium carbonate and 250% w/w of water for 30 min followed by a second soaking step with the addition of enzymes, bactericide and other chemicals.

For the second soaking step, 0.1% w/w bactericide Busan 85 and 0.25% w/w sodium carbonate were added in all the trials.

In the soaking named MF1, a traditional wetting agent and a traditional degreaser, respectively Indiwet OH30 and Indiwet L30 were used, and in the soaking MF2 two enzymes, Buzyme 148 (protease) and Buzyme 7707 (lipase), were used.

Table 1 shows the soaking procedure where the percentages of inputs were calculated based on the hide mass.

Table 1: Soaking procedures

Operations	Products	T/ ºC	%	Time	Control
Cleaning	Water	25	250	30 min	pH and weight
	Sodium Carbonate		0.25		
Soaking MF1	Water	25	250	24 h	pH, weight and conductivity /15'/1h/1.5h/2h/3h/ 4h/24h
	Sodium Carbonate		0.25		
	Busan 85		0.1		
	Indiwet OH30		0.3		
	Indiwet L30		0.2		
Soaking MF2	Water	25	250	24 h	pH, weight and conductivity 1'/15'/1h/1.5h/2h/3h/ 4h/24h
	Sodium Carbonate		0.25		
	Busan 85		0.1		
	Buzyme 148		0.1		
	Buzyme 7707		0.2		

To evaluate the soaking performance, pH value, conductivity and hide weight gain were measured at different intervals (1 and 15 minutes and 1, 1.5, 2, 3, 4 and 24 hours).

After each evaluation, the hide pieces and liquor samples were returned to the drums and the process continued until complete 24 hours.

Analysis

Different studies were performed to evaluate the soaking process: conductivity, pH value and hides weight gain.

In the soaking liquor the conductivity measurement was evaluated with Hach Conductivity/TDS meter, Consort C562 and the pH value controlled with Metrhom 691 pH Meter.

For the weight gain, the hides were drained by 2 minutes in order to standardize this procedure before the measurement in an analytical balance (Kern ALJ 220 – 4NM).

RESULTS AND DISCUSSION

In the experimental trials, all parameters were evaluated at zero time, before the addition of the skin to the soaking liquor.

Table 2 shows the pH values obtained for the different trials. The trial named MF1 refer to trial when a traditional wetting agent and a traditional degreaser were used, in the test named MF2 two enzymes were used, Buzyme 148 (protease) and Buzyme 7707 (lipase). MF1_G and MF2_G were tested with green skin (G). The trials with salted skin (S) were named with MF1_S and MF2_S.

This parameter shows a similar behavior in all the trials with a decreasing of 28% from initial (zero time) to final value (24 hours), except for the trial MF2_S which presents a decreasing of 40.5%. After 1 hour of soaking, there is a pH stabilization for all the trials between 8 and 9.5, except for the trial MF2_S.

Table 2: pH values obtained in the soaking tests in each interval of time

Hide	Green skin		Salted skin	
Test Samples time	MF1_G	MF2_G	MF1_S	MF2_S
0 min	11.31	11.34	11.46	11.47
1 min	10.72	10.44	10.82	11.20
15 min	10.29	9.94	10.21	10.33
1 hour	9.64	9.31	9.69	9.68
1.5 hours	9.28	9.08	9.38	9.07
2 hours	9.18	9.07	9.25	8.78
3 hours	9.00	8.94	9.08	8.38
4 hours	8.95	8.87	9.04	8.25
24 hours	8.06	8.26	8.24	6.83

In what concerns conductivity of soaking liquor, for green skin (Figure 1), the trial MF2_G (soaking with enzyme) reached the highest result followed by the soaking test with wetting agent and a degreaser (MF1_G). It is also observed that both trials become practically stable after 2 hours.

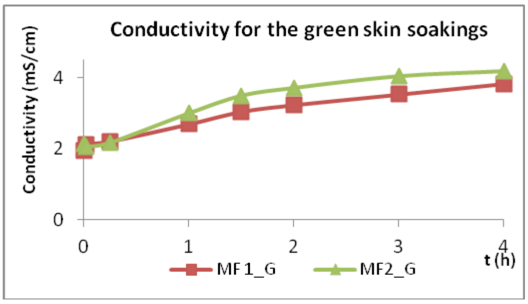

Figure 1. Conductivity values of green skin soakings for trials MF1_G and MF2_G

Figure 2 illustrates the results of conductivity for salted skin soakings. In this case, soaking with wetting agent and degreaser obtained higher results than with enzyme. However, the behavior is very similar for both trials.

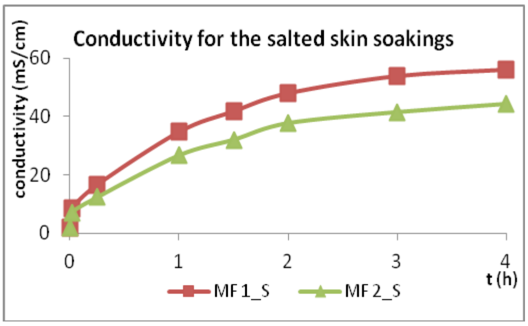

Figure 2. Conductivity values of salted skin soakings for trials MF1_S and MF2_S

For 24 hours trial time there weren't visible changes for the parameter studied (more 5.2% for MF1_S; more 10.1% for MF2_S) when compared with results obtained for 4 hours.

Comparing the conductivity of both liquors (green and salted skin), salted skin presents a higher conductivity than green skin, as was expected.

Figure 3 and Figure 4 represent the effect of soaking in the hide weight gain on green and salted skin respectively. The hide weight gain was analyzed to evaluate the evolution of hide rehydration, after water diffusion into the hide. The weight gain was calculated as the ratio between the weight change (difference between the final weight and the initial weight) and initial weight, in percentage.

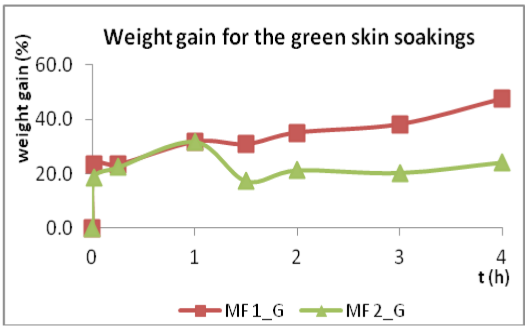

Figure 3. Hide weight gain evaluation for green skin for trials MF1_G and MF2_G

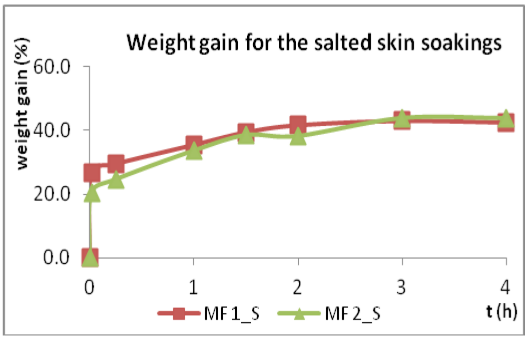

Figure 4. Hide weight gain evaluation for salted skin for trials MF1_S and MF2_S

Figure 3 shows significantly higher values for soaking with wetting agent and degreaser (MF1_G) than with enzyme (MF2_G), namely after 1 hour of soaking. After 1 hour for soaking with enzyme (MF2_G) there was a reduction in the weight gain, not expected.

In Figure 4, for salted skin soaking, the behavior is very similar showing the same performance for the enzyme soaking against the traditional soaking. For MF1, 42.5% was the gain for salted skin and 47% for green skin.

Table 3 shows values for tests after 24 hours. Ending 24 hours there weren't major changes for the parameter studied when compared with results for 4 hours.

Table 3: Hide weight gain for 24 hours

Test	Weight gain (%)	
	Green skin	Salted skin
MF1	42,6	41,1
MF2	25,2	41,6

Analyzing all the results obtained for 24 hours, MF1, and MF2 present a similar behavior for the salted skin with a result not expected for the green skin.

CONCLUSIONS

The necessity to optimize the leather process due to the huge investment and negative effects of using high quantities of water, chemical reagents and time, has led to this study.

Concerning the pH, after 1 hour of soaking, there is pH stabilization for all the trials between 8 and 9.5. The analysis of the conductivity showed that salted skin soaking bath presents a higher conductivity than green skin, as was expected. On the other hand, a similar behavior is observed for the two soaking systems. In what concerns the weight gain, the enzymes soaking achieved approximately the same results than the traditional soaking with a similar behavior.

In conclusion, it can be said that enzyme soaking has the same performance compared to the traditional soaking with the advantage of having a lower environmental impact on the waste water because enzymes are biodegradable compared to the traditional wetting and degreasing chemicals.

Acknowledgments

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INFLUENCE OF THE INCREASING WEIGHT OF THE BACKPACK ON THE BALANCE OF MOVEMENT TO PRIMARY SCHOOL STUDENTS

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INFLUENCE OF THE INCREASING WEIGHT OF THE BACKPACK ON THE BALANCE OF MOVEMENT TO PRIMARY SCHOOL STUDENTS

ABSTRACT. Nowadays, the backpack is becoming more and more important in people's daily life in our society. It has aroused the concern of the community that primary school students carry heavy bags. Heavy loading may cause some problems, like spinal, shoulder and back pain, etc. Consequently, it will affect the growth and development of students directly or indirectly. Thereby, the aim of this paper was to understand the influence of increasing the weight of the backpack on the balance of movement, and to explore the effect of heavy loading on the growth and development of those subjects. 100 healthy primary school students (7-12 years old) were recruited and they were guided in walking with a backpack loading of 5%, 10%, 15%, 20% and 25% body weight. Their kinematic and kinetic data were measured by Footscan plantar pressure system and 3D motion capture. Parameters of center of pressure and vector angles within two lower limb joints were calculated to quantify the relationship between the loading and balance. Our results show that an increase of weight of the backpack has limited effect on the track of the center of pressure, and pupils can cope with the balance risk brought by the increase of load. In order to maintain balance control, students adjust their posture to eliminate the balance risk factors caused by loading. While increasing of loading had a great effect on body posture, 15% BW (Body Weight) loading could be considered to be a safe value.

KEY WORDS: backpack load; center of pressure; vector angle; motion balance; primary school students

INFLUENȚA CREȘTERII GREUTĂȚII RUCSACULUI ASUPRA ECHILIBRULUI ÎN MIȘCARE AL ELEVILOR DE ȘCOALĂ PRIMARĂ

REZUMAT. În prezent, rucsacul devine din ce în ce mai important în viața noastră de zi cu zi. Acest lucru a stârnit îngrijorarea comunității privind greutatea genților transportate de elevii de școală primară. Supraîncărcarea poate provoca unele probleme, cum ar fi durerile de coloană, umăr și spate etc. În consecință, aceasta va afecta creșterea și dezvoltarea elevilor în mod direct sau indirect. Astfel, scopul acestei lucrări este de a înțelege influența creșterii greutății rucsacului asupra echilibrului în mișcare și de a explora efectul supraîncărcării asupra creșterii și dezvoltării acestor subiecți. Au fost recrutați 100 de elevi de școală primară sănătoși (cu vârsta cuprinsă între 7 și 12 ani) și li s-a cerut să se deplaseze cu un rucsac cu 5%, 10%, 15%, 20% și 25% din greutatea lor corporală. Datele cinematice și cinetice ale acestora sunt măsurate cu sistemul de presiune plantară Footscan și prin captarea 3D a mișcării. S-au calculat parametri precum centrul de presiune și unghiurile dintre vectori la două articulații ale membrelor inferioare pentru a cuantifica relația dintre încărcare și echilibru. Rezultatele noastre arată că creșterea greutății rucsacului are un efect limitat asupra traiectoriei centrului de presiune, iar elevii pot face față riscului de dezechilibru cauzat de creșterea greutății. Pentru a menține controlul asupra echilibrului, elevii își ajustează poziția pentru a elimina riscul de dezechilibru cauzat de încărcare. Deși creșterea greutății a avut un efect pozitiv asupra posturii corpului, încărcarea cu 15% din greutatea corporală ar putea fi considerată o valoare sigură.

CUVINTE CHEIE: încărcare rucsac; centru de presiune; unghi dintre vectori; echilibru în mișcare; elevi de școală primară

L'INFLUENCE DU POIDS CROISSANT DU SAC À DOS SUR L'ÉQUILIBRE EN MOUVEMENT CHEZ LES ÉLÈVES DE L'ÉCOLE PRIMAIRE

RÉSUMÉ. De nos jours, le sac à dos devient de plus en plus important dans la vie quotidienne. Ceci a soulevé l'inquiétude de la communauté concernant le poids des sacs portés par les élèves de l'école primaire. La surcharge peut causer certains problèmes, comme une douleur à la colonne, à l'épaule et au dos, etc. Par conséquent, la surcharge affectera directement et indirectement la croissance et le développement des élèves. Ainsi, le but de cet article est de comprendre l'influence du poids du sac à dos sur l'équilibre en mouvement et d'explorer l'effet de la surcharge sur la croissance et le développement de ces sujets. 100 élèves d'école primaire en bonne santé (âgés de 7 à 12 ans) ont été recrutés et invités à se déplacer avec un sac à dos avec 5%, 10%, 15%, 20% et 25% de leur poids corporel. Leurs données cinématiques et cinétiques ont été mesurées avec le système de pression plantaire Footscan et par la capture de mouvement 3D. Des paramètres tels que le centre de pression et les angles entre les vecteurs à deux articulations des membres inférieurs ont été calculés pour quantifier la relation entre la charge et l'équilibre. Nos résultats montrent que l'augmentation du poids du sac à dos a un effet limité sur la trajectoire du centre de pression, et les étudiants peuvent faire face au risque de déséquilibre causé par le gain de poids. Pour maintenir le contrôle de l'équilibre, les élèves ajustent leur position pour éliminer le risque de déséquilibre causé par le chargement. Bien que le gain de poids ait eu un effet positif sur la posture du corps, une charge de 15% du poids corporel pourrait être considérée comme une valeur sûre.

MOTS CLÉS : chargement du sac à dos ; centre de pression ; angle de vecteur ; l'équilibre du mouvement ; élèves de l'école primaire

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INTRODUCTION

Backpack load is becoming more and more important in people's daily life in our society. It has aroused the concern of the community that primary students carry heavy bags. Heavy loading may cause some problems, like spinal, shoulder, and back pain, etc. Consequently, it will affect the growth and development of students directly or indirectly [1, 2]. It was found that back pain was common in primary school students [3].

Backpack load inflicts external loading on a child's body and it changes the position of the center of gravity of the body. In order to maintain balance control and resistance, children would adjust their gait and posture. The method of biomechanical analysis was applied to analyze the body changes with different weight of the backpack of primary school students, according to the principle of biomechanics, so as to explore the influence on primary school students' growth and lay the foundation of the optimal designing of all kinds of healthy products. In current literature, scholars studied the effect of a backpack on human body posture and gait, such as plantar pressure/body deviation angle/muscle tone, etc. In accordance with the previous experimental results, the weight of students' backpack should be less than 10% of body weight [4], and 15% of body weight was the critical safety value [5].

Balance in movement is the steady state, the body adjusted the action, posture, or size of the force to maintain the steady state when the body imbalances, this is a complex process of dynamic balance. The selection of optimal position depends on the right combination of the target motion stability and flexibility. Balance control is an important function of the human body and its external behavior is the ability to keep stability of posture under any loading. The center of mass and center of pressure can reflect the ability of balance veritably.

Equilibrium and the angle dynamics were the most commonly used mechanics method to research balance. The research of the weight of children's backpack of Pau *et al*. showed that with the increasing of weigh, the center of pressure (COP) track length became longer and moved forward, and the lateral displacement of COP became smaller, these increased the discomfort and structural damage of the feet [6]. Research of Rugelj and Sevsek showed that COP track length and displacement increased with the weight of backpack linearly [7, 8]. The increasing of weight of a backpack would affect balance ability in multi-aspect, and body posture control often assessed by quantifying the range of the center of pressure. Singh and Koh assessed 17 pupils walking on a treadmill under different backpack weights and they suggested that with the increasing weight of the backpack, the body leans forward gradually and the increasing of weight would lead to changes in body posture [9]. Meyers-Rice *et al*. [10] analyzed the distribution of plantar force and postural sway in a sample of 10-year old children who carried a backpack of 5%, 10% and 15% of their body weight under static conditions. However limitations existed in the current studies: (1) the number of subjects used in the above were very few, which would cause deviation of the experimental results; (2) there was little study about the effect of backpack on motion balance in China; (3) no description on the relationship between the backpack weight and movement balance, and less quantitative evaluation index data representation.

On account of the limit of current studies, our study recruited 100 healthy primary school students in China aged between 7 and 12, and they were guided in walking with a backpack loading of 5%, 10%, 15%, 20%, and 25% body weight. Their kinematic and kinetic data were measured by Footscan plantar pressure system and 3D motion capture. Then the influences of the backpack weight on the motion balance of pupils were evaluated quantificationally.

METHODS

Subjects

The study recruited 100 healthy primary school students aged between 7 and 12 (Table 1) who came from a primary school at Guangzhou, Guangdong province, China. The inclusion criterions shown below were: (1) walking independently without support including orthopedic instrument; (2) no scoliosis; (3) feet without trauma. The aims and methods of this test were first explained to patients' parents and a formal approval was obtained before the test. Furthermore, this study was approved by the ethics committee of the university and all procedures were following with the principal of Helsinki Declaration.

Table 1: Demographic Information of Subjects

Age	7	8	9	10	11	12
N	14	14	21	26	20	5
Height/cm	121±9	127±10	131±11	137±16	142±10	145±6
Weight/kg	22.0±6.4	27.8±12.6	27.3±11.2	30.5±11.4	32.0±9.7	34.7±7.6
BMI	14.9±3.6	16.9±6.3	15.9±4.1	16.2±5.3	15.9±2.8	16.5±2.7

Devices and Settings

Children's plantar pressure was measured by Footscan pressure plate (one meter plate, RSscan Int., Belgium), they were guided in walking with a backpack load of 5%, 10%, 15%, 20% and 25% body weight respectively. The scanning frequency of this system is 250 Hz, pressure sensor density is 4/cm^2, and the range of measure is 0-200 N/cm^2. A two-step initial protocol was performed by the children and they were guided in walking with their selected speed through the pressure plate which was located in the middle of six-meter-long track [10]. Before the measurement, the system was calibrated: first a subject's weight was measured, then allowed to walk with their selected speed through the pressure plate, and the test system would adjust the weight value of actual and theory automatically so as to calibrate; and then three to five minutes warm up was provided.
Codamotion (Odin, Charnwood Dynamics Ltd, UK) was used to collect the motion track of key points with body movement. Before the measurement, the system was calibrated. All subjects were guided to become familiar with the experimental devices and process by testers and warmed up for one or two minutes. All the key points of subjects, including ear, shoulder, trochanter, knee, lateral malleolus, and fifth toe, were marked in turn (Figure 1).

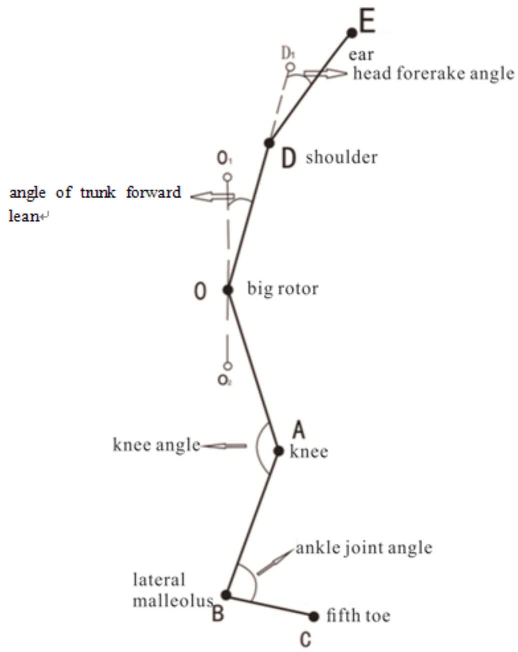

Figure 1. Graphic of Key Points of Codamotion

Plantar pressure test and CODA test were begun at the same time, all subjects were guided in walking with backpack loading of 5%, 10%, 15%, 20% and 25% body weight respectively. Three successful measures for plantar pressure test and CODA test were required.

Data Processing

COP Analysis

Any COPi was composed by coordination in the X and Y direction (Xi, Yi), as well as the time cost, hence, based on the coordination, we could calculate the minimum and maximum vibration in X (Xmin and Xmax) and Y (Ymin and Ymax) axis. The distribution of COP was a theory value, hence COP even exists when there was no pressure in midfoot (Figure 2).

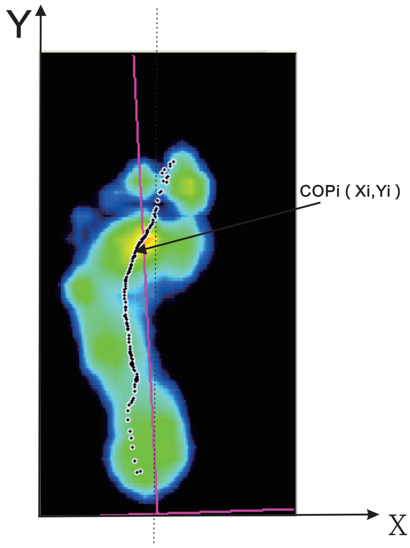

Figure 2. Trajectory of COP

On the basis of the analysis of the minimum in X axis (Xmin), maximum in X axis (Xmax) of COP and movement time, we got the deviation in X and Y axis (Dx, Dy) and relative deviation in X and Y axis (Dxrel, Dyrel) of COP, relative velocity (velocity and relative velocity in X axis: Vx, Vxrel; velocity and relative velocity in Y axis: Vy, Vyrel), sum and relative sum distance in X axis (SumX, SumXrel) and sum and relative sum distance in Y axis (SumY, SumYrel). The procedures of normalization of deviation, velocity and sum distance were shown below:

$$Dx = |X\max - X\min| \quad (1)$$

$$Dxrel = |X\max - X\min| / FW \quad (2)$$

$$Dy = |Y\max - Y\min| \quad (3)$$

$$Dyrel = |Y\max - Y\min| / FL \quad (4)$$

$$SumX = \sum (X_{i+1} - X_i) \quad (5)$$

$$SumXrel = \sum (X_{i+1} - X_i) / FW \quad (6)$$

$$SumY = \sum (Y_{i+1} - Y_i) \quad (7)$$

$$SumYrel = \sum (Y_{i+1} - Y_i) / FL \quad (8)$$

$$Vxrel = Dxrel / times \quad (9)$$

$$Vyrel = Dyrel / times \quad (10)$$

Vector Angle Analysis

Vector angle showed the space relationship of joint and it was developed by the plane constituting by the key points of joint. Data of subjects during normal walking was recorded by CODA, the vector angles included head fore rake angles, body fore rake angles, knee joint angles and ankle joint angles were calculated via space location of key points. Vector angles were needed to calculate amplitude of angle and the time when the angle reached peak and the maximum angle.

Statistical Analysis

The measures of each test were first averaged; all data were divided into groups according to backpack load, and the data of each group averaged; then One-Sample Kolmogorov-Smirnov confirmed that all data were following with the normal distribution and the result showed that all data were following with the normal distribution; meanwhile independent T test was used to verify if the data had significant differences between two feet and the results of independent T test was verified that two feet had significant differences, so data of right foot was selected for analysis; One-Way ANOVA was used to analysis the COP and vector angle under different backpack loads. All the statistical models were operated under SPSS (16.0 V, SPSS Inc., Chicago, USA) with a significant level of 0.05 and 95% confidence interval.

RESULTS

Result and Analysis of COP

The result of ANOVA analysis of all parameters under different backpack loading (Table 2).

Table 2: The Analysis Result of One Way ANOVA of COP

Backpack loading	Xmin (mm)		Xmax (mm)		Ymin (mm)		Ymax (mm)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0% BW	-10.1	4.4	19.6	5.3	22.4	7.2	214.4	20.2
5% BW	-10.2	5.1	19.4	5.6	22.2	4.9	217.5	15.1
10% BW	-10.0	5.1	18.8	5.7	22.4	4.9	215.6	20.3
15% BW	-10.1	5.3	18.5	6.0	22.3	5.6	215.6	19.6
20% BW	-9.4	4.6	18.6	5.7	21.3	5.1	210.8	30.3
25% BW	-9.8	5.0	19.2	5.7	22.2	6.5	217.0	17.7
	V-X		V-Y		SumX (mm)		SumY (mm)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0% BW	0.094	0.019	0.317	0.042	58.7	12.6	198.1	22.0
5% BW	0.093	0.015	0.324	0.032	57.3	9.4	198.6	15.4
10% BW	0.091	0.014	0.322	0.036	56.1	8.5	197.4	19.4
15% BW	0.092	0.016	0.318	0.037	57.3	10.7	197.0	18.9
20% BW	0.088	0.018	0.309	0.048	55.1	11.7	192.7	28.2
25% BW	0.089	0.015	0.314	0.036	56.8	10.2	199.1	18.7

As shown in Table 2, Ymax of COP increased with the increasing of backpack loading, while Xmax of COP was in contrast, both of the changes were slight. The P values of the groups were all larger than 0.05 in the range of 0.067~1. Hence, there was no significant difference on COP between different backpack loading.

Result of Joint Vector Angle Analysis

As showed in Table 3, the reaching time of max angle increased with the increasing of backpack loading, 0 vs 25% BW P=0.04, 5% BW vs 20% BW P=0.042, 5% BW vs 20% BW P=0.01; compared with 0% BW, backpack loading reduced the angle of trunk forward lean, 0 vs 5% BW P=0, 0 vs 10% BW P=0, 0 vs 15% BW P=0, 0 vs 20% BW P=0; the increasing of backpack loading also reduced the knee angle, 0 vs 25% BW P=0.036; changes of ankle joint angle were the same as the knee angles. 0 vs 5% BW P=0.013, 0 vs 15% BW P=0.014, 0 vs 20% BW P=0.01, 0 vs 25% BW P=0; the range of movement increased significantly with the increasing of backpack loading, 0 vs 20% BW P=0.01, 0 vs 25% BW P=0.02.

Table 3: The Analysis Result of One Way ANOVA of CODA

	Time fore rake of body		Time shoulder		P	Time knee		Time ankle	
	Mean	SD	Mean	SD		Mean	SD	Mean	SD
control	2.362	0.917	2.456	0.890	0vs25%BW P=0.04	2.607	0.954	2.206	0.974
5% BW	2.356	0.781	2.432	0.752	5%BWvs20%BW P=0.042	2.546	0.854	2.156	0.796
10% BW	2.423	0.860	2.535	0.830	5%BWvs25%BW P=0.01	2.637	0.933	2.247	0.887
15% BW	2.417	0.895	2.578	0.862		2.615	0.988	2.210	0.888
20% BW	2.498	0.939	2.671	0.899		2.625	1.002	2.270	0.935
25% BW	2.535	0.897	2.749	0.863		2.701	0.948	2.325	0.913

	Max Fore rake of body		P	Max shoulder		Max knee		P	Max ankle		P
	Mean	SD		Mean	SD	Mean	SD		Mean	SD	
control	30.0	11.2	0vs5%BW P=0	170.7	26.4	10.1	33.3	0vs25%BW P=0.036	133.2	8.0	0vs5%BW P=0.013
5% BW	23.6	11.9	0vs10%BW P=0	170.6	27.7	13.8	32.7		135.7	8.4	0vs15%BW P=0.014
10% BW	23.3	11.7	0vs15%BW P=0	170.1	28.0	14.8	32.3		135.2	7.9	0vs20%BW P=0.01
15%BW	24.0	11.7	0vs20%BW P=0	169.4	27.4	16.0	32.0		135.7	8.0	0vs25%BW P=0
20%BW	24.0	11.3		169.5	27.6	17.6	31.7		136.3	8.9	
25%BW	23.4	11.4		169.1	28.4	19.4	32.3		137.2	8.4	

	Body Amplitude		Shoulder Amplitude		Knee Amplitude		Ankle Amplitude		P
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
control	24.5	9.0	120.9	122.2	19.4	39.4	30.2	7.0	0vs20%BW P=0.01
5%BW	23.2	7.9	134.4	130.3	19.3	45.0	32.0	7.4	0vs25%WB P=0.02
10%BW	22.8	8.1	125.6	124.2	17.6	39.3	32.2	6.9	
15%BW	23.1	8.0	115.9	117.9	17.8	39.1	33.5	7.2	
20%BW	23.7	7.8	108.0	109.6	19.1	44.5	36.3	30.0	
25%BW	23.7	7.7	110.7	112.9	17.0	33.4	36.2	22.3	

Note: the vector angle of shoulder/ knee/ ankle in table was the supplementary angle of it in Figure 1.

DISCUSSION

Problems pertaining to overloading schoolchildren are a major concern. In this paper, parameters of center of pressure, front lean angle of head and trunk, vector angles within two lower limb joints and peak time of arrival angle were calculated to quantify the relationship between the loading and balance.

As you can see from the results, the increasing of backpack loading had no significant influence on COP, while it would increase the arrival time of peak value of all angles, and reduces the motion range of knee and ankle. We considered: on the one hand, the impact of weight on the various parameters of the COP was little, load increasing in pupils backpack has little influence on the movement balance when walking, pupils can respond to balance risk with the increase of the load. On the other hand, with the increase of the load, the time of the angle of trunk front lean reached the peak increased, and the parts of the knee and ankle movement amplitude decreased. It showed that children would adjust their posture to eliminate the risk factor from load increasing to maintain balance control. The increasing of backpack load changed the COP of the body, also increased moment of hip joint and contraction of abdominal muscle, and thereby weakened the ability of balance control. In order to control the balance of the body, children leaned forward to offset gravity loss of backward movement. Meanwhile, reduction of swing time and single support phase time were reduced.

In current literature, Hong *et al*. [4] showed that the increasing backpack loading increased the front rake angle of body significantly, especially the comparison between 15-20% BW and 0-10% BW. Range of motion of body decreased significantly when the loading was more than 20% BW. Hong *et al*. considered that preschoolers can quickly adapt to gait with the increasing of backpack loading. Malhotra and Sen Gupta [11] pointed out no significant changes in body posture at 10-20% BW loading. While the study of Pascoe *et al*. [12] found that carrying a two-strap backpack of 17% of the body weight of youths significantly promoted forward lean of head and trunk compared to walking without backpack. The past research suggests that load changed posture of body and affect motion balance. When the load was more than 15%, changes of body position were significant. However, the number of the existing research samples was few and its regional distribution was not widespread. Our study was based on a large number of samples, and the experimental result was more universal. Our study also confirmed that 15% BW was the boundary and the parameters lower than 15% BW had significant difference with the parameters over it. 15% BW was widely considered to be the safety loading value, and it had no significant influence on body position.

This study was the first to investigate the relationship between the load and movement balance from the center trajectories of pressure and body posture change. The parameters of center of pressure, front lean angle of head and trunk, vector angles within two lower limb joints and peak time of arrival angle were calculated to quantify the relationship between the loading and balance. The results showed that the impact of weight on the various parameters of the COP was not obvious, and pupils can deal with the balance risk of weight increase. In order to maintain balance control, children would adjust their posture to eliminate the risk factor from load increasing. 15% BW was widely considered to be the safety loading value.

CONCLUSION

In our research, the increasing of backpack loading had no significant influence on COP, while it would increase the arrival time of peak value of all angles, and reduces the range of motion of knee and ankle. As a result, pupils can cope with the balance risk increased with the increase of load, and corresponding measures have been taken to eliminate related risk factors.

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Authors' Contributions

YLM and CWY contributed to the conception, protocol development, and design of the study. ZJ and ZN participated in data acquisition, analysis, and interpretation. All authors have contributed significantly to the various stages in the writing of this manuscript and approved the final version of the paper. All authors agree with the order of presentation of the authors.

Competing Interests

None of the authors declare competing financial interests.

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ANALYSIS OF CHARACTERISTICS IN CHINA CLASSIC DANCERS' GAIT PATTERN

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ANALYSIS OF CHARACTERISTICS IN CHINA CLASSIC DANCERS' GAIT PATTERN

ABSTRACT. China Classic Dance is one of the most important and popular dancing in China and has become more and more popular from all over the world. However, the special gait patterns for the China Classic Dancers are not clear. The purpose of this study was to compare the characteristics of plantar pressure distribution in the China Classic Dancers and the non-dancers, and recognize if force transference happened. Gait data (PP, Fmax, PTI, FTI and FTIrel) from 93 China Classic Dancers and 30 non-dancers were analyzed. The plantar force transference was accessed with a load-transfer algorithm. Significant differences were found in plantar pressure distribution between the two groups: 1. maximum forces for China Classic Dancers significantly lower than the control group except the T1 and M2 regions; 2. peak pressures showed significant decrease in the China Classic Dancers except the M2 region; 3. the force-time integrals and pressure-time integrals in each region reduced significantly in comparison with the controls; 4. main significant load transferences were observed from T1, lateral forefoot (M3-5), midfoot and HM regions to the medial forefoot (M1-2) areas (T1, M3-5, MF, HM→M1-2). And the medial to lateral transferences were typical in toes and heel regions (T1→T2-5, HM→HL). These results suggested a typical gait patterns for the China Classic Dancers. Further investigation is needed in sports biomechanics and injuries for this special population.
KEY WORDS: China Classic Dance, plantar pressure, load transference

ANALIZA CARACTERISTICILOR TIPARULUI DE MERS AL DANSATORILOR DE DANS CLASIC CHINEZESC

REZUMAT. Dansul clasic chinezesc este unul dintre cele mai importante și populare dansuri din China și a devenit unul dintre cele mai populare din întreaga lume. Cu toate acestea, tiparele de mers specifice dansatorilor de dans clasic chinezesc nu sunt clare. Scopul acestui studiu a fost de a compara caracteristicile distribuției presiunii plantare ale dansatorilor de dans clasic chinezesc și ale non-dansatorilor și de a determina dacă a avut loc transferul de forță. S-au analizat date privind mersul (PP, Fmax, PTI, FTI și FTIrel) preluate de la 93 de dansatori de dans clasic chinezesc și 30 de non-dansatori. Transferul forței plantare a fost măsurat cu un algoritm de transfer de greutate. S-au constatat diferențe semnificative în distribuția presiunii plantare între cele două grupuri: 1. forțele maxime la dansatorii de dans clasic chinezesc au fost semnificativ mai mici decât în cazul grupului martor, cu excepția regiunilor T1 și M2; 2. presiunile maxime au prezentat o scădere semnificativă în cazul dansatorilor, cu excepția regiunii M2; 3. integralele forță-timp și presiune-timp au scăzut semnificativ în fiecare regiune în comparație cu grupul martor; 4. principalele transferuri semnificative de greutate au fost observate din zona T1, zona antepiciorului lateral (M3-5), zona mediană și HM către antepiciorul median (M1-2) (T1, M3-5, MF, HM→M1-2). Transferurile din zona mediană spre cea laterală au fost observate în regiunile degetelor și călcâiului (T1→T2-5, HM→HL). Aceste rezultate au sugerat un tipar de mers specific dansatorilor de dans clasic chinezesc. Sunt necesare investigații suplimentare în domeniul biomecanicii sportive și al leziunilor specifice acestei populații.
CUVINTE CHEIE: dans clasic chinezesc, presiune plantară, transfer de greutate

L'ANALYSE DES CARACTÉRISTIQUES DU MODÈLE DE LA MARCHE CHEZ LES DANSEURS CLASSIQUES DE CHINE

RÉSUMÉ. La danse classique chinoise est l'une des danses les plus importantes et les plus populaires de la Chine qui est devenue l'une des danses de plus en plus populaire dans le monde entier. Cependant, les modèles des danseurs classiques chinois ne sont pas clairs. Le but de cette étude a été de comparer les caractéristiques de distribution de la pression plantaire chez les danseurs classiques et les non-danseurs et de déterminer s'il y avait transfert de la force. On a analysé les données de marche (PP, Fmax, PTI, FTI et FTIrel) prises à partir de 93 danseurs classiques et 30 non-danseurs. Le transfert de la force plantaire a été mesuré avec un algorithme de transfert de poids. Il y avait des différences significatives dans la répartition de la pression plantaire entre les deux groupes: 1. les forces maximales aux danseurs de la danse classique chinoise ont été significativement plus faibles que dans le cas du groupe témoin, sauf pour les régions T1 et M2; 2. les pressions maximales ont montré une diminution significative pour les danseurs, à l'exception de la région M2; 3. les intégrales force-temps et pression-temps sont diminuées de manière significative dans chaque région par rapport au groupe de contrôle; 4. les principaux transferts de poids importants ont été observés de la région T1, la région latérale de l'avant-pied (M3-5), la région médiane et la région HM à la région médiane de l'avant-pied (M1-2) (T1, M3-5, MF, HM→M1-2). Les transferts de la région médiane vers les régions latérales ont été observés dans les doigts et le talon (T1→T2-5, HM→HL). Ces résultats suggèrent un modèle de marche spécifique aux danseurs de danse classique chinois. Des investigations complémentaires sont nécessaires dans le domaine de la biomécanique sportive et des lésions spécifiques de cette population.
MOTS CLÉS: danse classique chinoise, pression plantaire, transfert de poids

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INTRODUCTION

China Classic Dance began in 1950s, as a branch of the Chinese dancing art. It was a typical dance with classical styles created and evolved from Chinese national and folk dances, which combines dance, Chinese traditional opera, folk acrobatics and Chinese martial art etc. [1-3]. This style of dance is well known for dancers' body tenacity and 'hardness with softness'. There are three principles about movements and rhythm in China Classic Dance: circling with the body, rotating with the waist and reverse force, which are typically different from other dances like ballet or Latin [4]. More and more people especially children begin to learn China Classic Dance due to its aesthetic and gymnastic character.

Dancers, after long-term dancing trainings, get a stronger cardiovascular and respiratory system. Main techniques in Chinese Classic Dance have a strong impact on dancers' posture, muscle strength and ligament strength [5]. Notably, the dancers' forefeet tend to be stronger to grasp the ground more easily and dancers' flexibility and balance also get improved after training.

Overloaded structures of foot due to extreme body position would affect the higher body segments in return, which may contribute to arch collapse, joint sprain, hip and back pain, muscle strain, cervical spine injury and anterior knee pain. T.O. Smith *et al*. [6] did a survey to evaluate musculoskeletal health in retired professional ballet dancers in the United Kingdom, and found thirty-six percent of the respondents reported retiring from ballet dancers due to musculoskeletal injury and the common issues were hip and back pain (25%), hamstring injuries, ankle injuries, cervical spine injuries, and anterior knee pain (13% respectively). Megan Noon *et al*. [7] found that the top injuries of the Irish dancers included stress fractures (29.9%), patellofemoral pain syndrome (11.1%), sever condition (6.0%), ankle sprains (5.1%), posterior tibialis (4.6%), and plantar fasciitis (4.6%). And the majority of injuries were in the lower extremities (94.9%). It has been proved that ballet dancers had a special gait pattern compared with the non-dancers [8]. However, the previous study about dancers' plantar pressure and other musculoskeletal system parameters mainly focused on ballet and Latin or other dance types, rarely on Chinese Classic Dance [9-15]. It is an important issue for China Classic Dancers, trainers and learners to know the typical gait patterns and the relevant prevention. In this study, China Classic Dancers' plantar pressure patterns were measured and analyzed to fill the research blank in this field. The results will provide references for prevention and treatment of motor injury and foot disease.

METHODS AND MATERIAL

Participants

Ninety-three China Classic Dancers with no history of lower extremity injury in the past six months and no foot deformity were recruited in this study. Thirty healthy non-dancers within comparable criteria (age, height, weight, shoe size, dancing experience) were involved as the control group. Basic information of the subjects was shown in Table 1. Written informed consent was received from all participants prior to the test in accordance with the Declaration of Helsinki. The study was approved by the Ethics Committee of Sichuan University.

Table 1: Basic information of the participants

Groups	n	Age (year)	Height (cm)	Weight (kg)	Shoe size (mm)	Dancing experience (year)
Dancers	93	19 ±1	160.0 ±2.2	49.1 ±4.1	230 ± 10	11 ± 3
Non-dancers	30	21 ± 1	160.0 ±3.1	50.7 ± 2.1	230± 10	0

Apparatus

Plantar pressure data were collected using a Footscan® plate system (RSscan Inc., Belgium; Figure 1) with a sampling rate of 250Hz. The 1-m plantar pressure plate has 8192 force sensors, and its weight, dimensions and resolution are:

7.7kg, 1068mm × 418 mm × 12 mm, 7.62 mm × 5.08 mm, and 500 Hz, respectively. The plate can stand 200N/cm^2 at most.

Figure 1. Footscan® plate system

Procedure

The test was conducted in an indoor laboratory. The plantar pressure plate was installed in the middle of a 6-m rigid rubber track of same height, to estimate a natural walking condition. Prior to data collection there was a familiarization period to reduce targeting, determine a start position and ensure several steps were taken before walking over the plate. Subsequently, participants walked through the plates barefoot at a self-selected speed, using a "two-step" method, which confirmed two complete footprints on the plate (Figure 2). Five successful footprints of each foot were measured for data analysis.

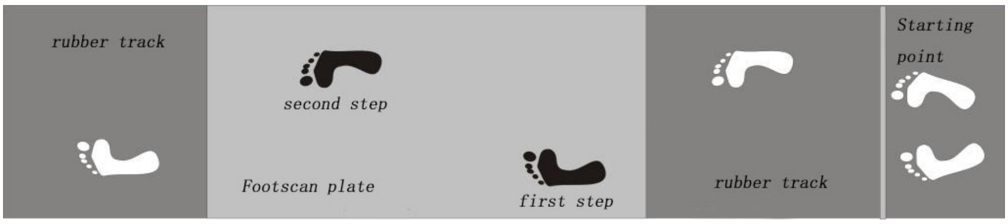

Figure 2. 'Two-step' method

Data Analysis and Reduction

The plantar surface was divided into ten regions (Figure 3) by Footscan software and artificial adjustment according to the anatomical principal and test requirements: Toe 1 (T1), Toes 2-5 (T2-5), the first to fifth metatarsal (M1, M2, M3, M4, M5), Midfoot (MF), Heel medial (HM), Heel lateral (HL). The plantar pressure data of the subjects' preferred foot (right foot) were analyzed only, since the China Classic Dancers rely more on their preferred foot during training. Plantar pressure variables involved in this study included: peak pressure (kPa; PP), maximum force (N; Fmax); the pressure-time integral (PTI); the force-time integral (FTI). Data from three relative stable measurements of each subject were averaged to minimize artificial accidental error and make the results more authentic.

Normality of the data was assessed using Kolmogorov-Smirnov test ($p>0.05$), and the differences between two groups were tested by Independent Samples T Test ($p<0.05$).

1st toe (T1)
2-5 toes (T2-T5)
1st metatarsal (M1)
2nd metatarsal (M2)
3rd metatarsal (M3)
4th metatarsal (M4)
5th metatarsal (M5)
Midfoot (MF)
Heel medial (HM)
Heel lateral (HL)

Figure 3. Regions of plantar surface

Load Transfer Algorithm

The FTI is a measure of force impulse or the load applied to the plantar region. The total impulse on the foot for the two groups may change if the gait patterns of the two groups are different. Thus, the relative FTI values (FTIrel) were required in this study. Then, the FTIrel difference in each plantar region of the two groups was calculated by the FTIrel mean of the dancer-group minus that of control-group for each area (Figure 2.a). A negative result would suggest that the relative load of the dancer-group was lower than that of the controls; vice versa for a positive outcome.

The posterior-anterior and lateral-medial force transferences happen along the foot arch. In which direction or order does the load transfer is still not clear, but it does not matter with the final transferring trend. Thus, a load transfer algorithm similar to that of a previous study was adopted in this work [16]. Details of the algorithm were presented as below:

Rule 1. The foot plantar is divided into four levels, based on the former regional partitions: the toe regions for Level 1, the forefoot region for Level 2, the midfoot region for Level 3 and the heel for Level 4.

Rule 2. The regional differences for the two groups are presented in each region. The load transfer from the area with a positive difference to the area with a negative outcome until a 0 is reached in one area, which would not participate in the transference any more.

Rule 3. The inter-level transferences happen first. And the force transfer between the neighbor regions prior to the others.

Rule 4. The intra-level transferences happen next. And the load transfer between the adjacent levels in preference to others.

RESULTS

Characteristics of Maximum Force

The results of maximum force were illustrated in Table 2. Heel, M1 and M2 regions were the main supporting and bearing areas, in which the maximum force was the largest. Significant differences were observed in all regions between the two groups except the M1 region. The maximum force value in the T1 region of the China Classic Dancers ($p<0.001$) was significantly higher than that of the non-dancers. However, the results of other regions (T2-5: $p=0.008$; M2: $p=0.021$; M3: $p<0.001$; M4: $p<0.001$; M5: $p=0.001$; MF: $p<0.001$; HM: $p<0.001$; HL: $p=0.001$) were lower compared with the control groups.

Table 2: Comparison of maximum force (N) between the two groups

	China Classic Dancers	Control group
T1	70.37 ± 42.99*	30.00 ± 20.98
T2-5	22.05 ± 21.44*	34.80 ± 21.45
M1	128.69 ± 65.94	91.12 ± 38.60
M2	108.24 ± 55.01*	147.41 ± 46.57
M3	72.00 ± 42.68*	137.10 ± 50.39
M4	48.73 ± 35.14*	77.23 ± 31.94
M5	24.93 ± 19.11*	46.40 ± 23.95
MF	58.60 ± 45.41*	111.02 ± 47.88
HM	125.48 ± 56.89*	183.05 ± 52.39
HL	114.12 ± 52.55*	143.46 ± 43.88

* represents $p<0.05$

Characteristics of Peak Pressure

The plantar peak pressure of China Classic Dancers were significantly lower in T1, T2-5, M1, M3, M4, M5, Midfoot, HM and HL regions than the controls ($p<0.05$). The peak pressure in M2 region ($p=0.222$) showed no significant difference (Table 3).

Table 3: Comparison of peak pressure (N/cm^2) between the two groups

	China Classic Dancers	Non-dancers
T1	4.70 ± 4.51*	6.88 ± 2.53
T2-5	1.27 ± 1.35*	1.69 ± 0.72
M1	5.29 ± 4.11*	7.00 ± 2.46
M2	11.36 ± 10.02	14.35 ± 2.79
M3	8.99 ± 8.19*	16.55 ± 4.74
M4	6.20 ± 6.19*	9.65 ± 3.76
M5	3.23 ± 3.55*	4.47 ± 2.32
MF	1.65 ± 2.06*	2.86 ± 0.86
HM	6.41 ± 5.26*	12.17 ± 2.25
HL	6.75 ± 5.41*	11.08 ± 2.99

* represents $p<0.05$

Characteristics of the Force-time Integral

The results in Table 4 suggested that the FTI values of the China Classic Dancers were significantly lower than those of the non-dancers in all plantar regions except for M1. This was in consistent with the result of the maximum force characteristics.

Table 4: Comparison of force-time integral (N·s) between the two groups

	China Classic Dancers	Non-dancers
T1	12.21 ± 9.55*	26.33 ± 10.88
T2-5	4.51 ± 6.72*	7.80 ± 6.28
M1	24.56 ± 16.53	26.54 ± 16.18
M2	31.05 ± 19.74*	46.35 ± 28.14
M3	19.96 ± 14.43*	44.55 ± 27.66
M4	12.79 ± 10.66*	26.59 ± 14.39
M5	7.58 ± 8.43*	16.11 ± 15.73
MF	14.70±13.54*	33.25 ± 17.63
HM	25.36 ± 13.99*	52.99 ± 38.09
HL	23.66 ± 15.30*	39.62 ± 28.91

* represents $p<0.05$

Characteristics of Pressure-time Integral

Significant differences were found in PTI values between two groups in all plantar regions ($p<0.05$) except for M2 ($p=0.123$), which was similar to the result of peak pressure characteristics. China Classic Dancers' PTI values reduced significantly in T1 (p<0,001), M3 (p<0,001), M4 (p=0,004), M5 (p=0,005), Midfoot (p<0,001), HM (p<0,001) and HL (p<0,001); and mildly reduced in T2-5 ($p=0.037$) and M1 ($p=0.046$) regions (Table 5).

Table 5: Comparison of pressure-time integral ($N/cm^2 \cdot s$) between the two groups

	China Classic Dancers	Non-dancers
T1	0.96 ± 0.59*	1.25 ± 0.55
T2-5	0.24 ± 0.27*	0.28 ± 0.15
M1	1.49 ± 0.79*	1.68 ± 0.77
M2	3.24 ± 1.88	3.64 ± 0.81
M3	2.78 ± 1.71*	4.31 ± 1.10
M4	2.00 ± 1.41*	2.72 ± 0.90
M5	0.82 ± 0.71*	1.22 ± 0.62
MF	0.41 ± 0.32*	0.72 ± 0.22
HM	1.73 ± 0.89*	2.70 ± 0.69
HL	1.78 ± 0.92*	2.40 ± 0.55

* represents $p<0.05$

Characteristics of Load Transference Mechanism

The FTIrel values and the FTIrel differences of the two groups were presented in Table 6. It suggested obvious load transference in Figure 4. The Heel and M1-2 regions were the main loading areas during the dancers' walking. The increase of FTIrel in M1-2 regions resulted from lateral forefoot, T1 and the HM areas. Furthermore, lateral to medial force transferences happened both in the toe and heel areas, which contributed a better load balance in the heel area.

Table 6: Comparison of the FTIrel (%) values between the two groups

	China Classic Dancers	Non-dancers	Differences (%)
T1	6.92	8.22	1.3
T2-5	2.56	2.44	-0.1
M1	13.92	8.29	-5.6
M2	17.60	14.48	-3.2
M3	11.32	13.92	2.6
M4	7.25	8.31	1.1
M5	4.30	5.03	0.7
MF	8.33	10.39	2.1
HM	14.38	16.55	2.2
HL	13.41	12.38	-1.1

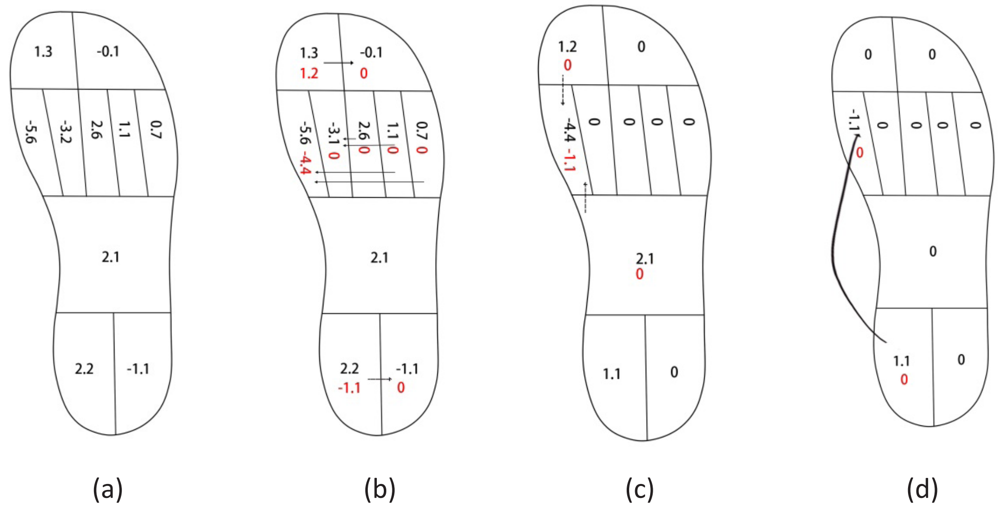

Figure 4. The load transference of the dancers compared with controls. (a) Regional differences in FTIrel between two groups; (b) Inter-level load transferences; (c) Intra-level adjacent force transferences; (d) Across level load transference. Figures in red color represented the rest of the FTIrel values after transferences.

DISCUSSION

The characteristics of the plantar pressure distribution were first investigated for China Classic Dancers during their normal walking in this study. In general, the results showed that the China Classic Dancers were significantly different from the non-dancers in all variables analyzed. And interestingly, significantly lower plantar pressure distributions were found in most plantar regions for the dancers. Special habitual toe-heel walking altered the ballet dancers' gait patterns even during daily normal walking [8]. China Classic Dancers need to practice to keep body tenacity and softness and it is important to involve muscle activation and ligament in some postures in their long-term dancing career. So, their movement e.g. walking would be milder and lighter than other people's. On the other hand, accumulating exercises may change their foot shape or even the musculoskeletal structures and kinematics characteristics of their lower extremities. Nili Steinberg *et al*. [17] found that 307 of the 1288 dancers were diagnosed as having scoliosis, and the scoliotic dancers presented a significantly higher prevalence of anatomical anomalies such as hallux valgus.

Significant differences have been found in the average EMG of tibialis anterior when Latin dancers danced wearing different heel height shoes [18]. Jeffrey *et al*. [14] noted incongruence of the talocrural joint and convergence of the tibia, talus, and calcaneus posteriorly. All these adaptations and changes were due to special dance-required postures and trainings. To achieve the extreme positions requested in the Chinese Classic Dance, dancers' musculoskeletal system may be adjusted to make some compensation like the foot pronation and toe-out gait of the ballet dancers. And this compensation mechanism plus long-term and intensive dancing training may change the dancers' gait stereotypes, such as the plantar pressure distribution.

Significantly lower peak pressure in all regions except M1 were found in China Classic Dancers. However, previous study found that there was a significant reduction of peak pressure in T2-5, M5 and MF regions and a significant increase in T1, M1 and M2 plantar regions in ballet dancers than in non-dancers. Especially in the T1 and M2 regions, the findings of the two studies were totally opposite. Furthermore, the pressure impulse in the China Classic Dancers tended to be more medial and the load in the subjects' heel was lower than that in the ballet dancers [8]. The disagreement might result from different calculating methods of peak pressure and different dancing types, as Chinese Classic Dance and ballet have different typical positions [19].

It was interesting to note that T1 region of the China Classic Dancers loaded significantly a higher maximum force but a lower peak pressure, which might be due to a larger contact area or a bigger and stronger hallux. The FTI and PTI of the hallux area were significantly lower in the China Classic Dancers, so the big toe was not the main loading area. The medial forefoot was found to have an obviously higher loading rate than that of the non-dancers, regarding the results of the FTI and the PTI.

The load transferences happened in China Classic Dancers compared with the controls were also investigated. Clear force transference was observed, confirming that the medial forefoot and the heel areas loaded the most impact during the dancers' walking, which would probably lead to damage in the areas. And the transferring trend to the medial forefoot may account for the great importance and function of the areas for the dancers. Another kind of interesting shifting was found in the toe and heel areas, medial to lateral transference, which resulted in a better load balance.

In this study, we focused only on the PP, Fmax, FTI and PTI parameters and the load transference of the dancers. So it is necessary to do more research about the lower extremity typical condition of China Classic Dancers such as the foot shape, surface EMG, kinematic features and kinetic characteristics etc. to strengthen the whole study system.

CONCLUSION

To our knowledge, this is the first study to investigate the characteristics of plantar pressure distribution of the China classic dancers during walking. The results did show many significant differences between the dancers and non-dancers. The four gait parameters and the load transference both suggested the typical characteristics of China Classic dancers' plantar pressure during natural walking is that relying more on the medial forefoot. So, it was necessary to take some targeted health promotion intervention for dancers' feet to prevent more foot diseases and sports injury such as designing special shoes for these China Classic Dancers in daily walking. Furthermore, it could be deduced from the different gait patterns between ballet dancers and China Classic Dancers that different dance types may affect the characteristics of the dancers' motor behaviors differently. This was also the basis of the rehabilitation of the different types of dancers' lower limbs.

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FEASIBILITY OF APPLICATION OF FINITE ELEMENT METHOD IN SHOE SLIP RESISTANCE TEST

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FEASIBILITY OF APPLICATION OF FINITE ELEMENT METHOD IN SHOE SLIP RESISTANCE TEST

ABSTRACT. Finite element analysis (FEA) has been widely used in engineering and construction in simulating forces and interactions and its application in footwear have become quite ripe by being researched for over 30 years. The aim of this study was to investigate the slip resistance of the outsole to learn (1) the feasibility of FEA in the test of outsole slip resistance (2) frictional interactions between outsole and contact surface by experiment test and finite element analysis. A static friction tester was used for static slip resistance test and a SATRA STM 603 slip resistance tester was used for dynamic slip resistance test. Outcome showed that value of SCoF was a little bit higher than that of DCoF both in ET and FEA, and value of coefficients obtained in ET was higher. With the increase of COF value, the displacement of outsole decreased while stress of the outsole increased. In conclusion, FEA application is feasible in footwear resistance testing. Stability of the outsole with superior slip resistance is good in both longitudinal and transverse direction. During walking, it has a strong resistance to the slipping tendency to prevent tumble and sprain.

KEY WORDS: Finite element model, Coefficient of friction, Slip resistance, Outsole

FEZABILITATEA APLICĂRII METODEI ELEMENTELOR FINITE LA TESTAREA REZISTENŢEI LA ALUNECARE A ÎNCĂLŢĂMINTEI

REZUMAT. Analiza elementelor finite (FEA) a fost utilizată pe scară largă în domeniul ingineriei şi construcţiilor pentru simularea forţelor şi a interacţiunilor, iar aplicarea acesteia în domeniul încălţămintei are o istorie îndelungată, fiind cercetată de peste 30 de ani. Scopul acestui studiu a fost de a investiga rezistenţa la alunecare a tălpii exterioare pentru a determina: (1) fezabilitatea FEA la încercarea de rezistenţă la alunecare a tălpii exterioare; (2) interacţiunile de frecare dintre talpa exterioară şi suprafaţa de contact prin testarea experimentală şi analiza elementelor finite. S-a folosit un aparat de testare a fricţiunii statice pentru testul de rezistenţă la alunecare statică şi un aparat de testare a rezistenţei la alunecare SATRA STM 603 pentru testul de rezistenţă la alunecare dinamică. Rezultatul a arătat că valoarea coeficientului de frecare în statică (SCoF) a fost puţin mai mare decât cea a coeficientului de frecare în dinamică (DCoF) atât în cazul testării experimentale, cât şi FEA, iar valoarea coeficienţilor obţinuţi în cazul testării experimentale a fost mai mare. Odată cu creşterea valorii COF, deplasarea tălpii a scăzut în timp ce presiunea asupra tălpii a crescut. În concluzie, aplicarea FEA este fezabilă în testarea rezistenţei la încălţăminte. Stabilitatea tălpii cu rezistenţă superioară la alunecare este bună atât în direcţia longitudinală, cât şi în cea transversală. În timpul mersului, talpa are o rezistenţă puternică la tendinţa de alunecare pentru a preveni căderea şi entorsa.

CUVINTE CHEIE: model cu elemente finite, coeficient de frecare, rezistenţă la alunecare, talpă exterioară

LA FAISABILITÉ D'APPLICATION DE LA MÉTHODE DES ÉLÉMENTS FINIS DANS L'ESSAI DE RÉSISTANCE AU GLISSEMENT DES CHAUSSURES

RÉSUMÉ. L'analyse par éléments finis (FEA) a été largement utilisée dans l'ingénierie et la construction pour simuler les forces et les interactions et son application dans le domaine de chaussures est devenue a une longue histoire grâce aux recherches menées depuis plus de 30 ans. Le but de cette étude a été d'étudier la résistance au glissement de la semelle extérieure pour apprendre : (1) la faisabilité de FEA dans le test de résistance au glissement de la semelle extérieure, (2) les interactions de frottement entre la semelle extérieure et la surface de contact par le test expérimental et l'analyse par éléments finis. Un testeur de frottement statique a été utilisé pour l'essai de résistance au glissement statique et un testeur de résistance au glissement SATRA STM 603 a été utilisé pour le test de résistance au glissement dynamique. Les résultats ont montré que la valeur du coefficient de frottement en statique (SCoF) était un peu plus élevée que celle du coefficient de frottement en dynamique (DCoF) dans le test expérimental et FEA, et que la valeur des coefficients obtenus dans le test expérimental était plus élevée. Avec l'augmentation du COF, le mouvement du pied diminuait tandis que la pression sur les semelles augmentait. En conclusion, l'application de FEA est réalisable dans les tests de résistance des chaussures. La stabilité de la semelle à résistance au glissement élevé est bonne à la fois dans les directions longitudinale et transversale. Pendant la marche, la semelle présente une forte résistance au glissement pour éviter la chute et l'entorse.

MOTS CLÉS : modèle d'éléments finis, coefficient de frottement, résistance au glissement, semelle extérieure

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INTRODUCTION

As a part in direct contact with the ground, the outsole undertakes most functions of footwear, in which the slip resistance is an important one. Slip resistance of outsole refers to its ability to stop slipping, which has a great impact on safety and comfort of footwear. An outsole of superior slip resistance can effectively prevent slipping and improve stability during walking to ensure personal safety.

Studies on shoe slip resistance have been reported worldwide. Some studies [1, 2] found that slip resistance of outsole can be evaluated by the use of static coefficient of friction (SCoF) and dynamic coefficient of friction (DCoF). Tsai *et al*. [3] discussed the effect of the hardness of outsole on slip resistance. Valiant *et al*. tested the slip resistance of outsole made of different materials. Ura *et al*. [4] studied temperature's influence on outsole slip resistance. Besides, there have been several studies [5-8] focused on the effect of outsole pattern. Li *et al*. [6] investigated the effect of depth of outsole pattern on slip resistance. Yamaguchi *et al*. [7] and Shao-Xun *et al*. [8] studied the relationship of different contact surfaces and the outsole pattern.

Although previous studies have carried out a lot of explorations on the slip resistance of outsole, they were simply limited to real experiment tests (ET). Detailed descriptions such as intrinsic-mechanism of slip resistance while the outsole was in contact with the contact surface was lacking, since the complicated interaction between outsole and contact surface including stress, strain and deformation is too difficult to be obtained by ET. However, this problem can be solved with the finite element method.

Finite Element Analysis (FEA) is an effective method for computer analysis of complex solid geometry involving several materials, with different properties [9]. FEA works by building a model and setting material properties along with boundary conditions. Then, by dividing the model into finite elements and inputting the environmental factors to obtain the result. The accuracy of the above operations will have a great impact on the accuracy of the final results.

In this study, both ET and FEA were used to investigate the slip resistance of outsole to learn (1) the feasibility of FEA in the test of outsole slip resistance; (2) frictional interactions between outsole and contact surface. The result would provide effective theoretical support for footwear test and design.

METHODS

Subject

There were two parts in this study. The first part was ET. The shoe tested was a high heel shoe with a 50mm heel-height. Its outsole was made of TPU, shore A 80° in hardness, 5mm in thickness. The pattern of the outsole was transverse stripes (Figure 1). The test was carried out on several square bricks. Slip resistance of outsole was evaluated by SCoF and DCoF. The second part was FEA. The three-dimensional finite element model of the outer sole was established in ANSYS 15.0 (V15.0, ANSYS Inc., USA). The static and dynamic slip resistance tests were carried out separately. The equivalent CoF was calculated to confirm the feasibility of the FEA and the slip resistance was investigated.

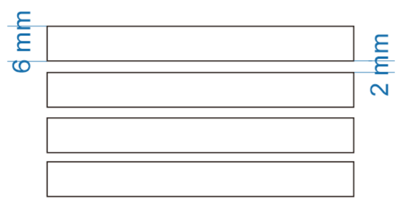


Figure 1. The pattern of the outsole test piece

Procedure

Experimental Test

The SCoF of the outsole was tested on a static friction tester. According to HG/T3780-2005 "Test method of static slip resistance for footwear" [10], a sample of outsole was cut out for testing. The test piece was put on a standard friction panel with a normal pressure of 27.3N from horizontal direction exerted during testing. The maximum pulling force in the case of sliding was recorded. The SCoF was calculated by the formula f=μN and the sample was tested 5 times for obtaining an average value.

SATRA STM 603 slip resistance tester (STM 603, SATRA, UK) (Figure 2) was used for the dynamic slip resistance test, according to SATRA TM144-2011 "Friction (slip resistance) of footwear and floorings" [11]. The instrument imposed a specified pressure on the test piece by a pressure device placed at the top to force contact with the test surface. The frequency and velocity of the friction test should be preset so that the relative motion of the shoe and the test surface will be carried out at constant speed. The force in the horizontal direction was measured by a horizontal sensor. The dynamic friction factor was calculated by the formula f=μN and the sample was tested 5 times for an average value.

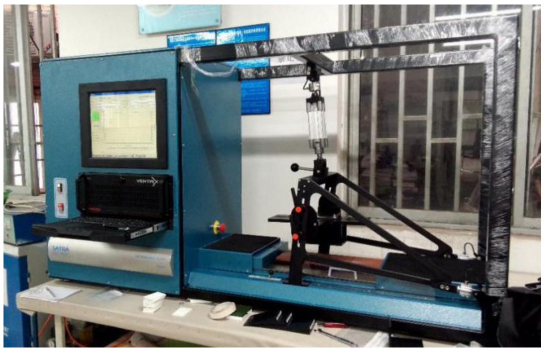


Figure 2. SATRA STM 603 slip resistance tester

Finite Element Analysis

Three-dimensional finite element model of outsole was established in ANSYS 15.0 according to a three-dimensional scanned model, for analysis of the SCoF and DCoF. The static slip resistance was tested by the test piece (Figure 3A) of outsole while the dynamic slip resistance test used the entire outsole for testing (Figure 3B). Furthermore, the deformation while the outsole was in contact with the floor surface was studied by finite element modeling.

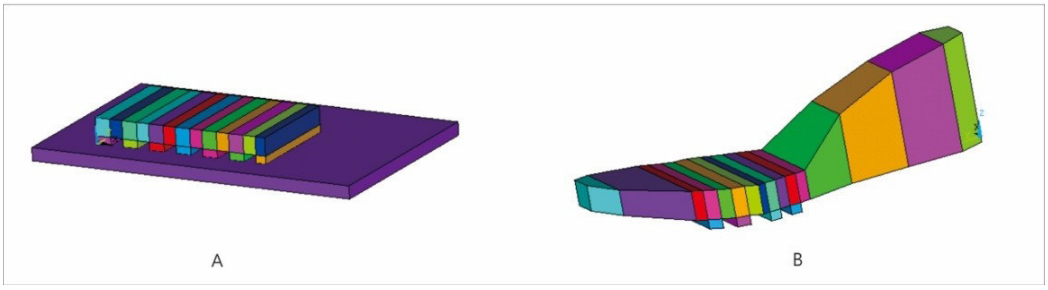


Figure 3. The 3D geometric model: (A) the model of the outsole test piece and (B) the model of the outsole

The Classic Mechanical APDL Product Launcher was used for analysis. ANSYS15.0 LS – DYNA modular was used on the outsole finite element model for displaying dynamics analysis and the element type was 3D Solid164.

The material of the outsole was defined as thermoplastic elastomer, the modulus of elasticity was set to 7.8*106 Pa and Poisson ratio was set to 0.47. The rigid body was used to simulate the ground and all degrees of freedom on the ground were restricted. The meshed model is shown in Figure 4.

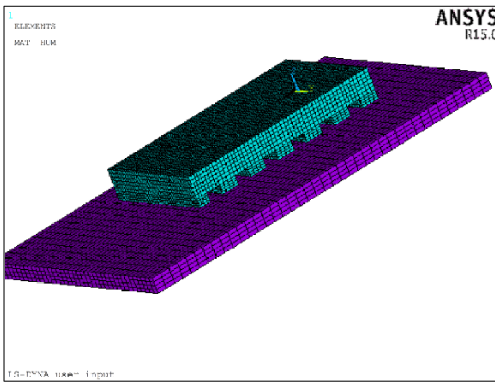


Figure 4. Meshing of the finite element model in static friction testing

Dynamic slip resistance testing was a little bit complex as forces from both transverse and vertical direction were exerted. FEA on dynamic slip resistance is different from ET. The DCoF is also a preset value in the FEA because DCoF is only determined by the property of the material. DCoF in this paper was set to 0.4, 0.5 and 0.6. The meshed model is shown in Figure 5.

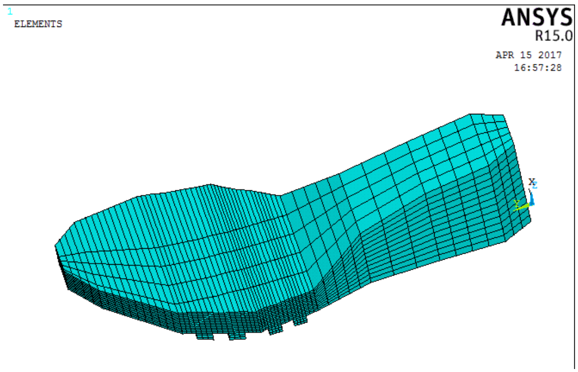


Figure 5. Meshing of the outsole model with ANSYS

Velocity boundary conditions were set to move the outsole relative to the floor. The contact pressure was controlled by the vertical displacement of the nodes on the top of the outsole [12]. This downward movement continued until an average normal force of 400N was achieved. The force was set to match the experimental conditions that were used in the ET that is of the same value of magnitude of normal force during walking. The second loading step moved the nodes on the top surface of the outsole in the shear direction at the desired speed relevant to slipping.

The equivalent CoF was calculated by the ratio of average shear force to the average normal force between the two surfaces in step two. Deformation and Stress of outsoles under different COF values were recorded.

RESULTS

Experiment Test

Under dry condition, SCoF between outsole and contact surface was 0.565 and DCoF was 0.554 after taking average.

Finite Element Analysis

Equivalent CoF Obtained in FEA

The equivalent SCoF in finite element test was 0.602 and the equivalent DCoF was 0.589.

Static Slip Resistance Test

The static friction deformation cloud chart of the outsole test piece model is shown in Figure 6. It shows that the outsole deformed during static friction process. The force in transverse direction of the node was 0.0226 N. The maximum stress of the node was 8*105Pa and the minimum stress of the node was -3.09*104Pa.

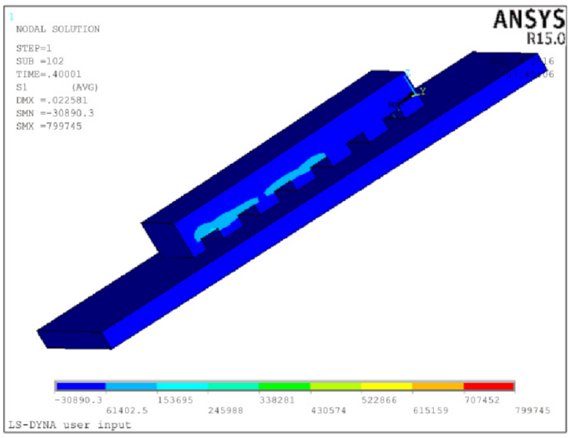


Figure 6. The finite element analysis results of outsole test piece model

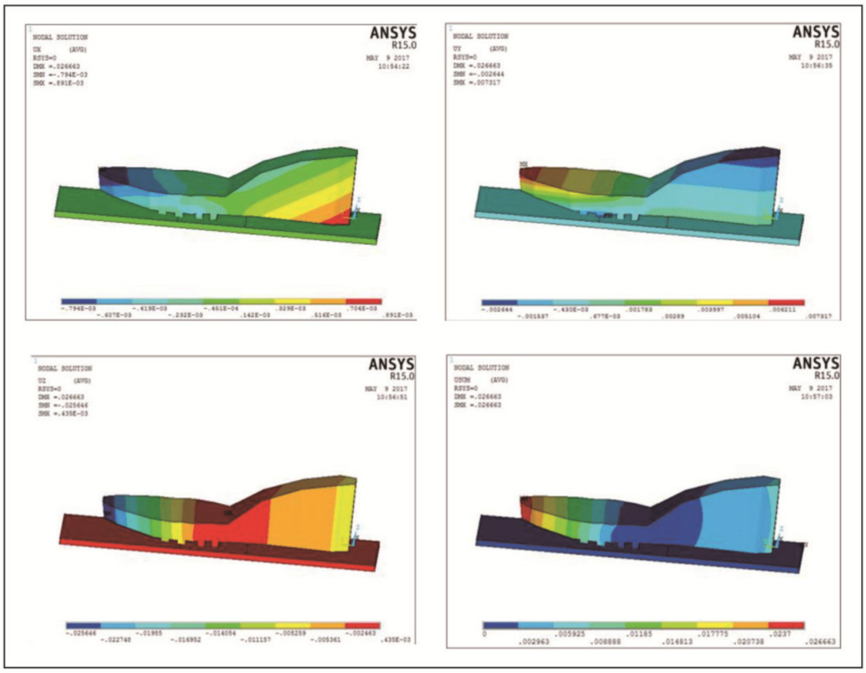
Dynamic Slip Resistance Test

The result of dynamic friction test was calculated according to the preset parameters. Displacement data of outsoles under different COF values is shown in Table 1.

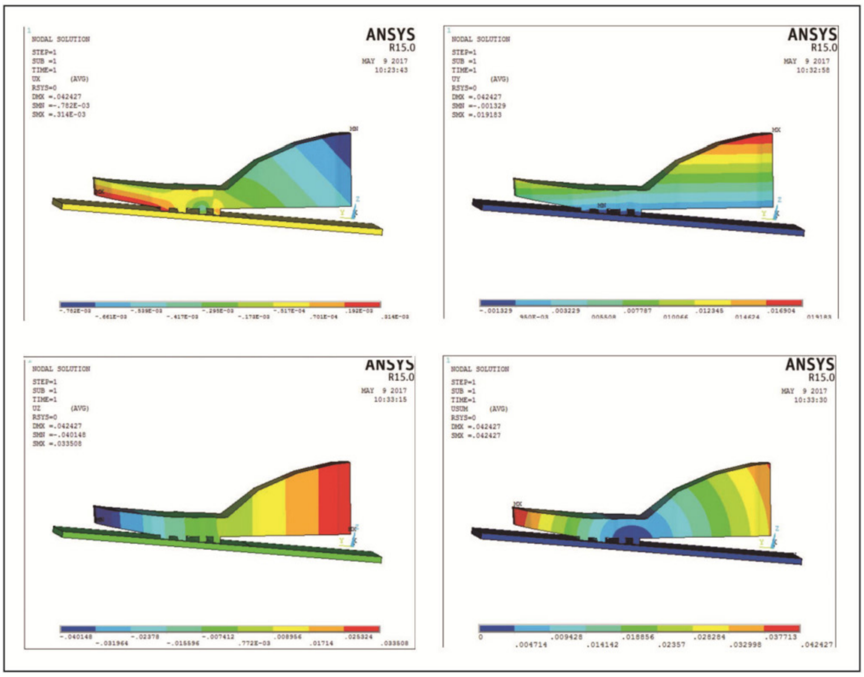
Table 1: The displacement data of outsoles under different COF values

COF 0.4			COF 0.5			COF 0.6		
Direction	Displacement /mm		Direction	Displacement /mm		Direction	Displacement /mm	
	Max	Min		Max	Min		Max	Min
X	0.3	-0.8	X	0.2	-0.5	X	0.9	-0.8
Y	19.2	-1.3	Y	10.9	-2.1	Y	7.3	-2.6
Z	33.5	-40.1	Z	13.5	-34.3	Z	0.4	-25.6
Maximum displacement	42.4		Maximum displacement	36		Maximum displacement	26.7	

It can be seen from Table 1 that the bigger the COF is, the smaller the maximum displacement of the outsole will be. The change of displacement in Y (anterior-posterior) direction was consistent with the change of maximum displacement. There was no apparent regularity found in the lateral displacement in X (medio-lateral) direction with the change of COF value. The displacement in Z (vertical) direction decreased with the increase of COF value. The displacement images of testing outsoles under different COF values are shown in Figure 7.



A



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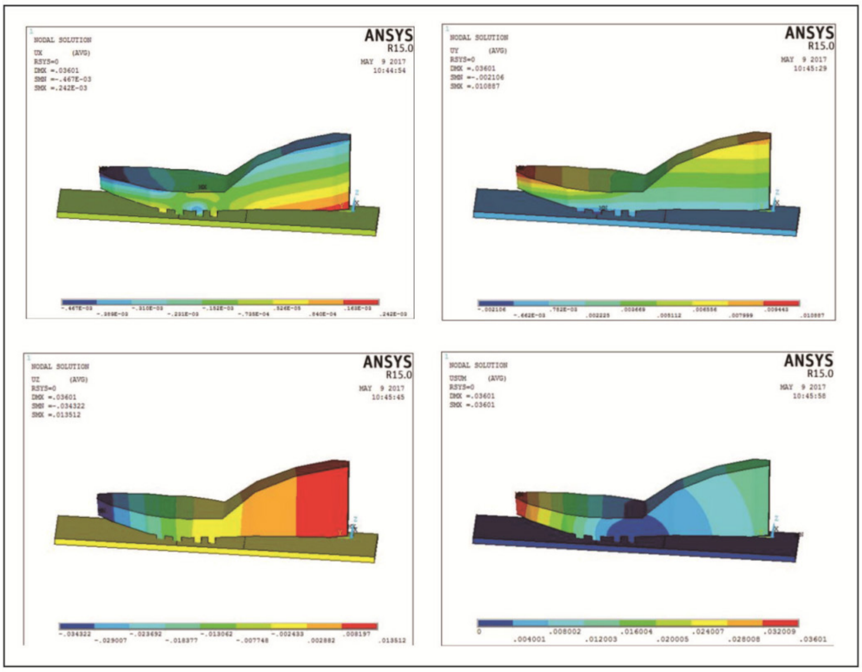


C

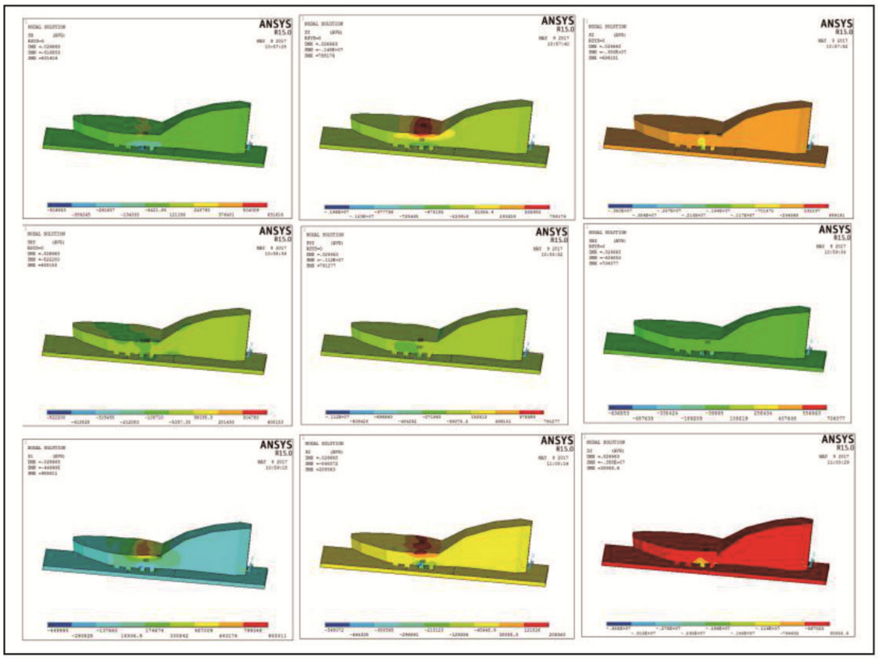
Figure 7. The displacement images of outsoles under the COF value of 0.4 (A), 0.5 (B), 0.6 (C)

The stress data of outsoles under different COF values is shown in Table 2.

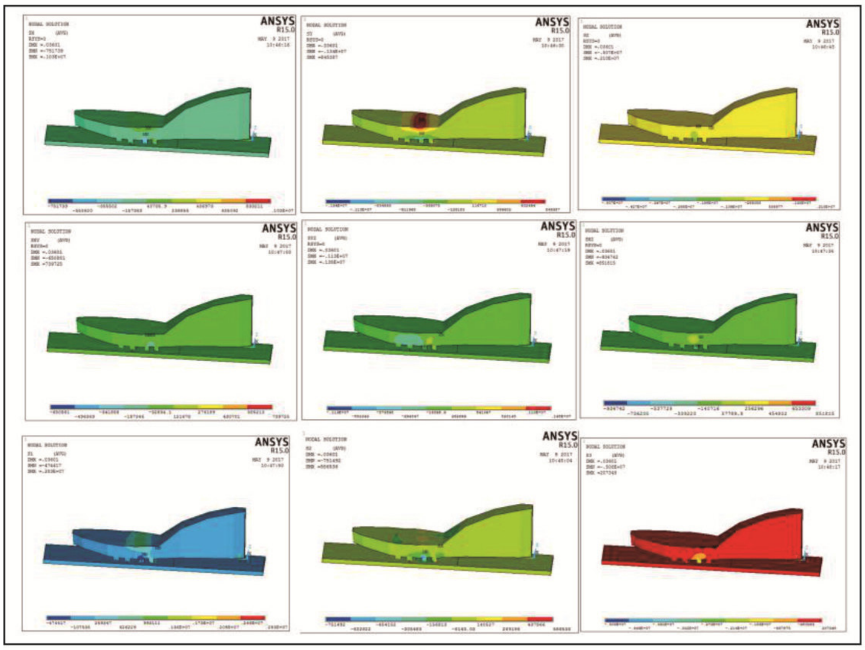
Table 2: The stress data of outsoles under different COF values

Direction		Stress/MPa Max	Stress/MPa Min	Direction	Shear stress /MPa Max	Shear stress /MPa Min
COF 0.6	X	1.37	-0.95	XY	1.03	-0.72
	Y	1	-1.44	YZ	2.22	-1.38
	Z	3.42	-6.24	XZ	0.98	-1.16
COF 0.5	X	1.03	-0.75	XY	0.74	-0.65
	Y	0.85	-1.34	YZ	1.38	-1.13
	Z	2.1	-5.07	XZ	0.85	-0.93
COF 0.4	X	0.63	-0.52	XY	0.41	-0.52
	Y	0.79	-1.48	YZ	0.79	-1.12
	Z	0.7	-3.5	XZ	0.71	-0.64

Table 2 shows that the maximum and minimum stress of the outsole increased with the increase of COF. The magnitude of the preset dynamic friction factor has influence on the force in X, Y and Z directions. Stress images of testing outsoles under different COF values are shown in Figure 8.



A



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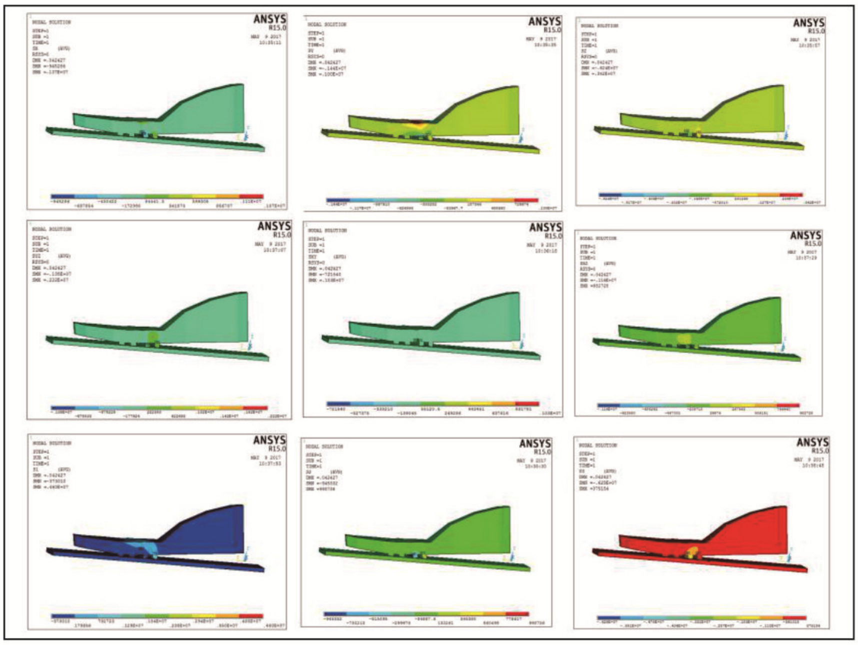

C

Figure 8. The stress images of testing outsoles under the COF value of 0.4 (A), 0.5 (B), 0.6 (C)

DISCUSSION

In this study, the CoF of the TPU outsole of a female high-heeled shoe was tested by ET and FEA. The two results were so closed, that finite element model can be considered a reliable alternative to the outsole slipping test. Additionally, we further investigated the deformation and stress of the outsole in the process of static friction and dynamic friction through the analysis process. The relationship between the deformation and stress of the outsole and COF was obtained and the effect of COF on slip resistance was explained.

Although finite element model was entirely established with reference to the entity one and the parameters of the FEA were also set completely according to the actual experimental conditions. There were still some deviations between the results of FEA and ET. These might be due to the influence of contamination in the contact surface and changing environmental temperature. Those factors would affect the final value of COF. In addition, finite element model was simplified for the convenience of calculation, and the pressure exerted on the foot from human body was simulated by the direct force method. Those practices might lead to errors.

The results showed that both in the ET and FEA the static friction factor was slightly larger than the dynamic friction factor and ranges from 0.55-0.60. It was similar to the results of previous studies [13]. The difference in the results may be caused by the hardness of outsole, the spacing and width of the outsole pattern and the experimental environment.

The study of Grönqvist *et al*. [2] indicated that the antiskid property of the outsole can be evaluated with the friction coefficient between the sole and the contact surface. The bigger the friction factor is, the better the slip resistance will be. This was consistent with the results of finite element analysis in current study. Table 1 showed that the displacement in both Y and Z directions decreases with the increase of COF which reveals that the transverse and vertical stability of the outsole with larger COF is much better to prevent tumble and sprain.

Table 2 shows that the stress of each node in the outsole increased with the increase of COF. This was in consistence with Coulomb friction law and the result of previous researches. Xiao *et al*. [14] studied antiskid property of airport pavement. They regarded the size of the stress as an indicator of the antiskid property. The larger the stress is, the better the anti-skid property will be. This is the same with the results in Table 2. We suspect that the outsole with lager COF has a strong resistance to the tendency of slipping due to a larger deformation caused by a larger stress.

Moreover, FEA shows that the stability of the outsole with superior slip resistance is stable both in the longitudinal and transverse directions. During walking, it has a strong resistance to the slipping tendency to prevent tumble and sprain. In future research, more diversified finite element analysis should be applied on the antiskid property of the outsole with different patterns and hardness. In order to improve the reliability of finite element analysis, the model should be more in line with the entity and the simulate conditions should be constantly adjusted to match the real condition. Meanwhile, the experimental test should be used as a proof of the finite element method.

CONCLUSION

Overall, although small deviation exists, FEA must be the future development trend in the shoe testing field. With the advantages of low cost, quick analysis and wide applicability, FEA will be used in more fields in the future [1].

Acknowledgement

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STUDIES ON WATERPROOFING WET-WHITE LEATHER

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STUDIES ON WATERPROOFING WET-WHITE LEATHER

ABSTRACT. Water resistance remains one of the more difficult goals to attain in leather manufacture. Although much is known from a scientific perspective, a problem persists when waterproofing wet-white leathers. The aim of this work was the study of the effect of different retanning agents on the waterproofing of wet-white leather produced by glutaraldehyde and syntan pre-tannage process. For that, a waterproofing process based in a waterproof fatliquor and a fluorocarbon based chemical, was tested applying different retanning resins, vegetable extracts and a dispersing agent to small leather pieces. Water resistance was evaluated by water absorption during 30 min in a static water bath at 25ºC. It was shown that retanning agents reduce water resistance when compared with the standard process without them. The reduction effect is stronger when a normal retanning acrylic resin, natural chestnut extract, and a dispersing agent are used. The water resistance reduction effect of tara extract, mimosa extract, quebracho extract, melamine resin, dicyandiamide resin and styrene maleic resin is not so evident. This work needs to be continued in order to evaluate other retanning chemicals, pass to a larger scale and then evaluate the water resistance by the common methods of the tanning industry.

KEY WORDS: leather, waterproof, wet-white

STUDII PRIVIND IMPERMEABILIZAREA PIELII WET-WHITE

REZUMAT. Rezistența la apă rămâne unul dintre obiectivele mai dificile de atins în procesul de fabricare a pieilor. Deși se cunosc multe din punct de vedere științific, o problemă persistă atunci când se realizează impermeabilizarea pieilor wet-white. Scopul acestei lucrări a fost de a studia efectul diferiților agenți de retăbăcire asupra impermeabilizării pieilor wet-white pretăbăcite cu glutaraldehidă și sintani. Pentru aceasta, a fost testat un procedeu de impermeabilizare bazat pe un agent de ungere rezistent la apă și un produs pe bază de fluorocarbon, prin testarea unor rășini de retăbăcire, extracte vegetale și un agent de dispersie pe bucăți mici de piele. Rezistența la apă a fost evaluată prin absorbția apei timp de 30 de minute într-o baie de apă statică la 25°C. S-a demonstrat că agenții de retăbăcire reduc rezistența la apă în comparație cu procesul standard fără acestea. Efectul de reducere este mai puternic atunci când se utilizează o rășină acrilică de retăbăcire obișnuită, extract natural de castan și un agent de dispersie. Efectul de reducere a rezistenței la apă al extractelor de tara, mimosa, quebracho, al rășinii melaminice, al rășinii diciandiamide și al rășinii maleice stirenice nu este atât de evident. Această cercetare trebuie continuată pentru a evalua alte substanțe chimice de retăbăcire, pentru a trece la o scară mai mare și apoi pentru a evalua rezistența la apă prin metodele uzuale în industria de pielărie.

CUVINTE CHEIE: piele, impermeabil, wet-white

ÉTUDES SUR L'IMPERMÉABILISATION DE LA PEAU WET-WHITE

RÉSUMÉ. La résistance à l'eau reste l'un des objectifs les plus difficiles à atteindre dans la fabrication du cuir. Bien que beaucoup de choses soient connues d'un point de vue scientifique, un problème persiste lors de l'imperméabilisation des peaux wet-white. Le but de cet article a été l'étude de l'effet de différents agents de retannage sur l'imperméabilisation des peaux wet-white obtenues par pré-tannage au glutaraldéhyde et aux syntans. Pour cela, un procédé d'imperméabilisation à base d'un agent graisse résistant à l'eau et d'un produit chimique à base de fluorocarbone a été testé en appliquant différentes résines de retannage, des extraits végétaux et un agent dispersant sur de petits morceaux de peau. La résistance à l'eau a été évaluée par l'absorption d'eau pendant 30 minutes dans un bain d'eau statique à 25°C. Il a été montré que les agents de retannage réduisent la résistance à l'eau par rapport au processus standard qui ne les utilise pas. L'effet de réduction est plus fort lorsqu'une résine acrylique de retannage classique, un extrait naturel de châtaigne et un agent de dispersion sont utilisés. L'effet de réduction de la résistance à l'eau de l'extrait de tara, de l'extrait de mimosa, de l'extrait de quebracho, de la résine de mélamine, de la résine dicyandiamide et de la résine styrène maléique n'est pas si évident. Ce travail doit être poursuivi afin d'évaluer d'autres produits chimiques de retannage, passer à plus grande échelle et ensuite évaluer la résistance à l'eau par les méthodes courantes de l'industrie du cuir.

MOTS CLÉS: cuir, imperméable, wet-white

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INTRODUCTION

Water resistance remains one of the more difficult goals to attain in leather manufacture. Although much is known from a scientific perspective, a problem persists when waterproofing wet-white leathers. A survey of commercially available chemicals is found on the market for a successful waterproofing of wet-blue leather [1]. The performance of these chemicals, when used in wet-white leather, is not the same because the substrate is very different. The demand of chromium free leathers has increased last years and the need to improve the water resistance of these leathers gains importance.

There are many factors that influence the waterproofness of leather, mainly the process and chemicals used in leather manufacture: surfactants, tanning agents, retanning and fatliquoring agents, and finishing agents.

Degreasing and soaking of hides must be carried out carefully with the minimal amount of surfactants. Complete penetration during neutralization is very important. The longer the neutralization time the better for thicker substrates. A good neutralization will allow deeper penetration of the hydrophobic fatliquor. The addition of waterproofing fatliquor is recommended to be done in two or more portions, the first to the retanning bath before the retanning agents and the other in a new bath after retanning and dyeing [2]. Fatliquoring agent plays an important role in the waterproofing of leather, the deeper the fatliquoring the better will be the results for waterproofing [3].

The main process used for chrome-free leathers is a glutaraldehyde and syntan tannage. This tannage can cause some problems to the waterproofing process because glutaraldehyde blocks the majority of cationic collagen groups and chromium absence prevents the fixation of hydrophobic agents inside the substrate because of the missing cationic valences [4].

Some authors give new ideas and suggest new ways to improve the water resistance of wet-white leather, from fluorocarbons to plasma technology [5-8].

In order to know more about the water resistance of wet-white leather, the authors intended to begin a work researching some practical aspects of the waterproofing process. This work is the first part of the research and has been done to evaluate the effect of retanning agents in a waterproofing process based in a known waterproof fatliquor from Atlas Refinery and a fluorocarbon based chemical, Indinol FW, developed by INDINOR, a chemical company located in Portugal.

EXPERIMENTAL

Materials and Methods

The raw material used in this work was wet-white leather prepared by INDINOR, using a glutaraldehyde (Fortan GL) and syntan (Inditan VOC liq.) pre-tannage. The wet-white leather, thus prepared, with a shrinkage temperature of 78ºC, was shaved to a thickness of 1.4 mm and subjected to a waterproofing process according to Table 1 to test the effect of different retanning agents. For all the trials, small pieces of wet-white were used, about 80 g, always from the same zone near the back-bone. The chemicals used were all obtained from INDINOR, and the trials were carried out using small laboratory drums at ISEP, with temperature and speed control. Chemical quantities were based on the weight of shaved wet-white hide pieces used.

After this process the hide pieces were left to rest for 48 hours, squeezed, dried and stacked. Then, the water resistance was evaluated according to the next method: a small piece with about 4 to 6 g was cut, weighed, poured into static water at 25ºC for 30 min, removed from water and weighed again. The water absorption was calculated as the percentage of weight increase based on the initial weight.

Several trials were carried out to evaluate the effect of different retanning agents on the waterproof effect against a standard process with no retanning agent and where the running time of waterproof fatliquor was 180 min.

RESULTS AND DISCUSSIONS

After stacking, the hide pieces were evaluated for the water resistance, and the results are presented in Figures 1, 2 and 3.

Figure 1 shows a reduction in water resistance when resins are applied, with a stronger effect for acrylic resin, comparing to the standard process.

Table 1: Waterproofing process

Process	Chemical	Chemical Quantity (%)	Time (min)	T (ºC)
Washing	Water	300	15	35
		Drain		
Neutralization	Water	150	90	35
	Sodium Formiate	2		
	Sodium Bicarbonate	1		
		pH Control (≈ 6) and drain		
Washing	Water	300	15	40
		Drain		
Retanning	Water	100	60	40
	Atlasol WRM*	6		
	Indinol FW	6		
	Retanning Agent	10	120	
Fixation	Water	50	5	60
	Formic Acid	1	60	60
		Drain		
Waterproofing	Water	100	50	50
	Indinol FW	4	30	50
	Formic Acid	0.5	15	50
	Lutan FN**	3	45	50
		Drain		
Washing	Water	300	15	25
		Drain		

*Waterproofing fatliquor from Atlas Refinery;
** Aluminium salt from BASF.

After this process the hide pieces were left to rest for 48 hours, squeezed, dried and stacked. Then, the water resistance was evaluated according to the next method: a small piece with about 4 to 6 g was cut, weighed, poured into static water at 25ºC for 30 min, removed from water and weighed again. The water absorption was calculated as the percentage of weight increase based on the initial weight.

Several trials were carried out to evaluate the effect of different retanning agents on the waterproof effect against a standard process with no retanning agent and where the running time of waterproof fatliquor was 180 min. Table 2 shows the trials description.

Table 2: Retanning agents applied in the different trials

Trial	Retanning Agent
T1	No Retanning agent added
T2	Fortan A40 (acrylic resin)
T3	Fortan CM/N ECO (melamine resin)
T4	Fortan DC (dicyanodiamide resin)
T5	Fortan SML (styrene maleic resin)
T6	Natural Chestnut extract
T7	Tara extract
T8	Mimosa extract
T9	Quebracho extract
T10	Natural Chestnut extract + 2% Inditan RS (dispersing agent)
T11	Tara extract + 2% Inditan RS
T12	Mimosa extract + 2% Inditan RS
T13	Quebracho extract + 2% Inditan RS

Figure 2 shows a reduction in water resistance when vegetable extracts are applied, with a stronger effect for natural chestnut, comparing to the standard process.

Figure 3 shows a higher reduction in water resistance when a dispersing agent is used to improve the penetration of vegetable extracts, comparing to the standard process.

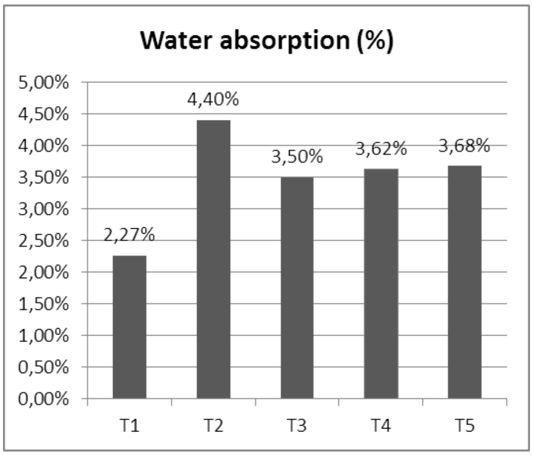

Figure 1. Water absorption for retannage with resins

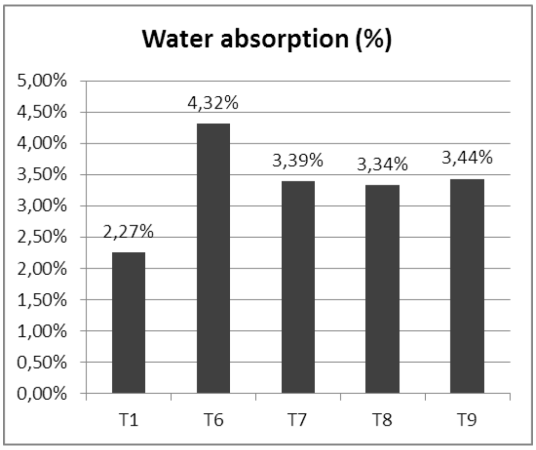

Figure 2. Water absorption for retannage with vegetable extracts

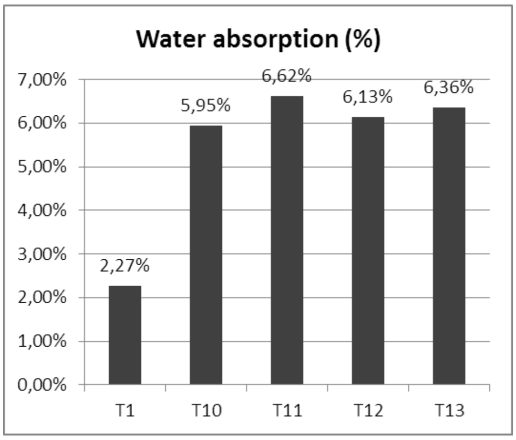

Figure 3. Water absorption for retannage with vegetable extracts and dispersing agent

As we can see from Figures 1, 2 and 3, the effect of retanning agents leads to a reduction in water resistance, mainly when chemicals with dispersing properties are used.

CONCLUSIONS

The aim of this work was the study of the effect of retanning agents on the water resistance of leather based in wet-white tanning.

It was shown that water resistance is affected by retanning agents, with more evidence for the acrylic resin, for natural chestnut extract and mainly for dispersing agents.

In the future, it will be important to test this process with other retanning chemicals, pass to a larger scale and then evaluate the water resistance by the common methods of the tanning industry. Another important work is the comparison of this waterproofing process applied in wet-white versus wet-blue.

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APPLICATION OF QFD METHOD IN FITNESS FOOTWEAR PRODUCTION

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APPLICATION OF QFD METHOD IN FITNESS FOOTWEAR PRODUCTION

ABSTRACT. In order to obtain a better product it is important to integrate the consumer requests in all production levels, starting with research, design and till the end of production process. One of the most popular methods used to increase the quality of a product is Quality Function Deployment. The result of application of QFD method in footwear is presented in this paper. The consumer requests are expressed by completing a questionnaire. The group of respondents consists of men and women, between 20 and 50 years old, who practice fitness more than twice a week. Their opinions are inventoried, analysed and in the end, the most important ones are the input information for the quality house. The result of the study is a better product and for the producers a guideline to obtain a product according to consumer expectations.

KEY WORDS: Quality Function Deployment, fitness footwear, quality house.

APLICAȚII ALE METODEI QFD ÎN PRODUCȚIA ÎNCĂLȚĂMINTEI PENTRU FITNESS

REZUMAT. Pentru obținerea unui produs de încălțăminte superior este important să fie integrate cerințele consumatorilor în toate fazele de obținere, începând de la cercetare, proiectare și până la finalul procesului de producție. Una din cele mai populare metode de a crește calitatea unui produs este desfășurarea funcției calității (QFD). Această lucrare prezintă aplicarea metodei pentru un produs de încălțăminte. Opiniile consumatorilor au fost exprimate cu ajutorul unui chestionar. Grupul țintă este format din bărbați și femei, cu vârste cuprinse între 20 și 50 de ani, care practică fitness mai mult de două ori pe săptămână. Cerințele lor au fost analizate, iar cele mai importante au ajutat la construcția casei calității. Rezultatul studiului îi ajută pe producători să obțină produse conform așteptărilor consumatorilor.

CUVINTE CHEIE: QFD, încălțăminte sport, casa calității

APPLICATIONS DE LA MÉTHODE QFD DANS LA PRODUCTION DES CHAUSSURES SPORT

RÉSUMÉ. Afin d'obtenir un produit de qualité supérieure, il est important d'intégrer les exigences du consommateur dans toutes les phases de la production, à partir de la recherche, de la conception et jusqu'à la fin du processus de production. L'une des méthodes les plus populaires pour augmenter la qualité d'un produit est le déploiement de la fonction qualité (QFD). Cet article présente l'application de cette méthode dans la production de chaussures. Les opinions des consommateurs ont été exprimées à l'aide d'un questionnaire. Le groupe cible comprend des hommes et des femmes de 20 à 50 ans qui pratiquent le fitness plus de deux fois par semaine. Leurs besoins ont été analysés, et les plus importants ont contribué à construire la maison de la qualité. Le résultat de l'étude aide les producteurs à obtenir les produits attendus par les consommateurs.

MOTS CLÉS : déploiement de la fonction qualité, chaussures sport, maison de la qualité

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INTRODUCTION

In last years, the footwear market has been under a strong and constantly increasing pressure. It is a pressure of overproduction produced by the big number of the actors involved, like companies, designers, sellers. The level of the competition is very high and, nowadays, to stay on the market means care about the customer and "to hear" the voice of the consumer.

According to Yoji Akao, the founder of QFD method, "Quality Function Deployment (QFD) is a method for satisfying customers by translating their demands into design targets and quality assurance points." This method can be used to design any product, process or activity. QFD method is applying a graphic model named Quality House.

In this paper, for a good and easy understanding of this method, is presented a case study for sports shoes used for fitness.

MATERIALS AND METHODS

The case study has two parts: the investigation of client's demands using a questionnaire, and building a Quality House.

The method used for the investigation of consumer's demands was a questionnaire. The quiz contained 10 items exploring the sports shoes, the raw materials they are made from, brand, price, followed by four questions regarding demographic aspects such as gender, age, education level and income level of the respondent.

The sample consists of consumers (male and female) who practice fitness at the gym. The clients were asked to be part of the study and complete the survey. The sample consists of 30 individuals, 21 men and 9 women, ages 18-40, who exercise more than two times per week.

In process of Quality House Development are five important steps:

Step 1: Establish requirements for the product design;

Step 2: Setting product functions;

Step 3: Establish the product concept taking in consideration the similar products of two competitors;

Step 4: Preliminary design of the product;

Step 5: Final constructive design of the product.

EXPERIMENTAL

Consumer's Demands

The first part of the survey investigates the type of shoes used during exercises, the materials they were made from, the brand and the price.

For more than half of respondents, 53.33%, the brand is the key factor when they make a purchase, followed by materials and price, 23.33%.

The second part of the survey is to find out the interest of the consumers regarding characteristics of the sport for fitness.

For fitness, 66.7% of the respondents prefer textile shoes because of their flexibility and comfort, 30% of interviewees are wearing shoes made from textiles and leather. They prefer textiles due to the comfort, dryness of the foot, the weight of the shoe and the style.

The features pursued by consumers are: 70% want comfort (dry feet, without cold/warm sensation), 53.3% look up for flexibility, 10% prefer light shoes and another characteristic is to wash easily (on washing machine).

When it comes to lock system, 53.3% of respondents prefer shoe lace, followed by elastic lace (30%) and Velcro system (10%).

The Building of the Quality House

The Quality House construction may be difficult at the first sight, but QFD is based on simple concepts rather than high technology. Developing process of Quality House must focus on consumers' needs, because they are the target group; the QFD team must identify these needs and using marketing skills, they have to find a way in order to satisfy the consumers.

Establish Requirements for the Product Design

Consumer needs are often unclear and vague technically speaking. Some of these needs are not realistic so the QFD team has to decide if they will be accepted or not. The needs were classified as primary and secondary requirements (table 1).

Table 1: Primary and secondary requirements

TO BE...	
Made of textile	Sole materials
	Upper materials
	Lining materials
Blue / black	Color
Price: 200-300 lei (40 – 50 Euro)	
Flexible	Flexibility
	Sole hardness
Dry feeling	Air permeability
	Water permeability
Lock system	

Setting Product Functions

Consumers' needs should be expressed using technical vocabulary to be easily understood by specialists in the design and production departments. Technical characteristics must be measureable because the results will be compared with the normal size and they will be part of the product starting from the design to the whole life cycle of the product.

The purpose of Quality House is to design a new product or to modify an existing one in order to satisfy or to exceed the consumer needs. Each characteristic should respond at least to one consumer requirement.

For the analyzed product, the consumer demands were classified in table 1, and the technical characteristics found by specialists after analyzing these requirements are presented in table 2. The arrow indicates a change of the requirement.

Table 2: Technical characteristics

Characteristics	Evolution
Upper materials	-
Lining materials	-
Color	-
Air permeability	↑
Water permeability	↑
Upper elasticity	↑
Sole materials (density)	-
Sole hardness	↓
Lock system	-

Establish the Product Concept

The purpose of this phase is to compare each requirement with every characteristic in order to identify a connection and to determine the intensity (strong, medium, weak, null) for each interaction. This stage can become very complicated because each consumer demand can influence several characteristics; the higher the number of requirements, the harder it will be to build the matrix for this phase. To make it easy, symbols or color codes can be used, as follows:

Code 9; Purple – strong connection;
Code 3; Green – medium connection;
Code 1; Yellow – weak connection;

	Upper materials	Lining materials	Color	Water permeability	Air permeability	Upper elasticity	Sole materials (density	Sole hardness	Lock system	Analyzed product	Competitor A	Competitor B
Made of textile	9	9								5	5	3
To be flexible	3	3				9	3	9		4	4	2
To stay fix on the foot									9	5	4	3
To feel dry	3	3		9						4	4	2
To "breathe"	3	3			9					4	3	2
To be blue/black			9							2	5	4
To be affordable	9	9	1	9	9	3	9	1	1	3	5	3

Figure 1. Connections between consumer needs and technical characteristics

A white box represents the absence of any connection.

Using symbols or color codes the Quality House becomes more friendly and easy to be understood by consumers who lack experience/ knowledge about technical terms in footwear. After filling in the matrix, it must be verified to see if there are blank rows or columns; in this case there is no link between consumers' requirements and technical characteristics.

For example if the customer wants to feel his feet dry (not to sweat), this means, in technical characteristics, a strong connection (9) with permeability and a weak connection (3) with the raw materials for linings and the upper, thereby the sole hardness has no influence on consumer's initial demand.

The "roof" of the Quality House is represented by establishing interaction between technical design characteristics. The "roof" will have the shape of a triangle table placed above the technical features. The code color used is:

Code +9; Purple – strong positive connection;

Code +3; Green – positive connection;

Code -3; Blue – negative connection;

Code -9; Grey – strong negative connection;

The QFD team should use the same code color in each step. This diagram helps the QFD team to identify the characteristics which are in conflict because compromises will have to be made. If these compromises are not resolved in the design stage, it is possible to make some changes later which means higher costs and customer demands will not be satisfied completely resulting an improperly quality product.

Making decisions regarding this compromise is a difficult process that involves many departments in the company, and ultimately leads to a short period of obtaining the product.

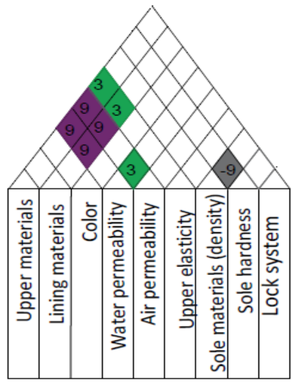


Figure 2. Connections between technical design characteristics

Preliminary Design of Product

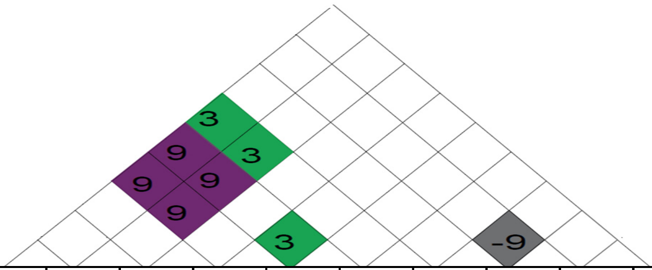
Preliminary design of product consists in comparing, by consumer and the QFD team, three products: the analyzed product, Competitor A, Competitor B (similar products of competitors) and evaluation of requests and technical features. This stage includes two phases: the first one is competitiveness evaluation from the point of view of the consumer and the second one refers to the technical competitiveness evaluation.

1. Evaluation from the point of view of the consumer

For each requirement the consumer indicates a number on a scale from 1 to 5 regarding competitiveness of the product under review compared to the products of Competitor A and Competitor B (one means weak and five strongest). The consumer also makes a hierarchy of these three products.

This method of evaluation shows whether the client claim is fulfilled, on one hand, and highlights the areas of the company that need to be changed in order to improve the design process, on the other hand.

Based on this analysis, strengths and weaknesses can be identified; the weaknesses can be improved by redesigning.



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To "breathe"	3	3			9					4	3	2
To be blue/black			9							2	5	4
To be affordable	9	9	1	9	9	3	9	1	1	3	5	3

Figure 3. Requirements Matrix – technical characteristics with evaluation of the competitiveness of the products

The house "foundation" includes the size and the measure unit of each characteristic making a technical assessment of the product analyzed towards the two competitors.

2. Technical competitive evaluation

This technical analysis is very useful to identify some issues that have been neglected by QFD team in the design process. If there is a strong connection between a technical descriptor and a consumer requirement, then the competitiveness evaluation from the point of view of the consumer should be compared with the technical competitiveness evaluation.

If the technical evaluation shows that the analyzed product is superior than competitors' products, then the evaluation from the point of view of the consumer should indicate a better grade. If there are some differences in consumer perception it means that there are design errors that need to be corrected or eliminated.

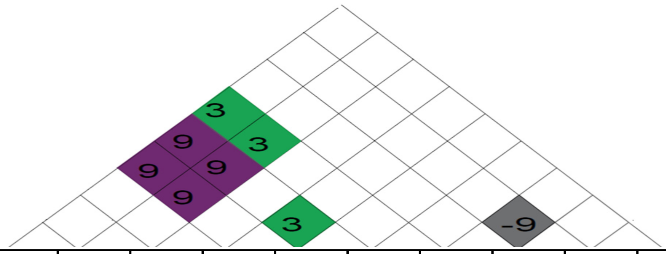
Final Constructive Design of the Product

The consumer should establish the importance of each request, that is why the quality house will grow with new columns which contain, among relative importance, four elements: target value, scale-up factor, sales point and absolute weight.

Relative importance is calculated by the QFD team for each technical descriptor.

To determine the relative importance, a survey and a scale from 1 to 10 are used, where 10 represents maximum importance and 1 minimum importance.

The QFD team must be very careful to quantify these values because the client's actions may not accurately reflect the perceived importance. For example a consumer can be influenced by the shoe brand instead of the footwear features.



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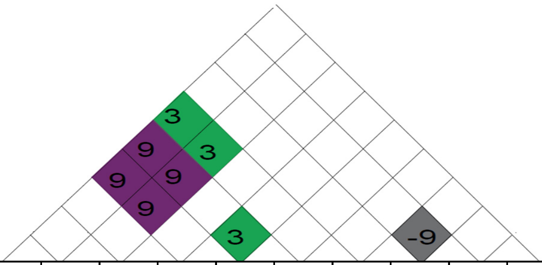
To be blue/black			9							2	5	4
To be affordable	9	9	1	9	9	3	9	1	1	3	5	3
				↑	↑	↑		↓				
	Textile	Textile	Scale 1 to 10	mg/24h	l/m²g	effort %	g/m³	Shore O				
Analyzed product	100	100	5	800	0,7	20	1,3	60	8			
Competitor A	60	100	7	400	0,4	28	1,5	93	10			
Competitor B	40	70	9	5	0,3	12	1,3	88	6			

Figure 4. Requirements Matrix – technical characteristics with evaluation of the competitiveness of the products



Interaction between technical features
Code +9; strong positive;
Code +3; positive connection;
Code -3; negative connection;
Code -9; strong negative connection;

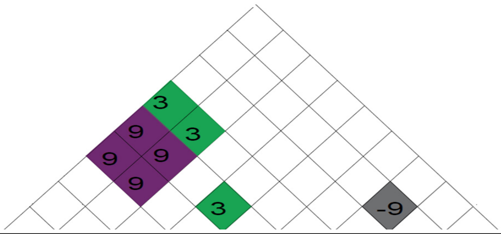
	Upper materials	Lining materials	Color	Water permeability	Air permeability	Upper elasticity	Sole materials (density)	Sole hardness	Lock system	Analyzed product	Competitor A	Competitor B	Target value	Scale-up factor	Seles point	Absolute weight
Made of textile	9	9								5	5	3	5	1	2	20
To be flexible	3	3				9	3	9		4	4	2	5	1,25	2	25
To stay fix on the foot									9	5	4	3	5	1	1,2	7,2
To feel dry	3	3		9						4	4	2	4	1	1,6	12,8
To "breathe"	3	3			9					4	3	2	5	2,5	1	12,5
To be blue/black			9							2	5	4	4	1,33	1,4	13
To be affordable	9	9	1	9	9	3	9	1	1	3	5	3	5	1,25	2	25

				↑	↑	↑		↓	
	Textile	Textile	Scale 1 to 10	mg/24h	l/m^2g	effort %	g/m^3	Shore °	
Analyzed product	100	100	5	800	0,7	20	1,3	60	8
Competitor A	60	100	7	400	0,4	28	1,5	93	10
Competitor B	40	70	9	5	0,3	12	1,3	88	6

Establishing interaction between consumer needs and technical design characteristics

Code 9; Purple – strong connection;
Code 3; Green – medium connection;
Code 1; Yellow – weak connection;

Figure 5. Requirements Matrix – the importance of the requirements



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To be flexible	3	3				9	3	9		4	4	2	5	1,25	2	25
To stay fix on the foot									9	5	4	3	5	1	1,2	7,2
To feel dry	3	3		9						4	4	2	4	1	1,6	12,8
To "breathe"	3	3			9					4	3	2	5	2,5	1	12,5
To be blue/black			9							2	5	4	4	1,33	1,4	13
To be affordable	9	9	1	9	9	3	9	1	1	3	5	3	5	1,25	2	25

				↑	↑	↑		↓	
	Textile	Textile	Scale 1 to 10	mg/24h	l/m²g	effort %	g/m³	Shore °	
Analyzed product	100	100	5	800	0,7	20	1,3	60	8
Competitor A	60	100	7	400	0,4	28	1,5	93	10
Competitor B	40	70	9	5	0,3	12	1,3	88	6
Technical difficulty degree	5	5	1	8	9	10	7	7	1
Target value	100	100	9	900	0,8	26	1,3	88	10
Absolute weight	237	237	52	135	153	111	93	97	52
Relative weight	486	486	126	232	342	264	192	238	77,8

Establishing interaction between consumer needs and technical design characteristics

Code 9; Purple – strong connection;
Code 3; Green – medium connection;
Code 1; Yellow – weak connection;

Figure 6. Requirements Matrix – technical design characteristics

1. Target value

The column for target value is using the same scale used for competitive evaluation for the analyzed product (5 the most competitive, 1 the lowest level of competitiveness). In this column the QFD team is developing its strategy.

2. Scale-up factor

Scale-up factor is the ratio between the target value and competitive evaluation of the analyzed product by each demand of consumer. Usually, the value of scale-up factor is higher than 1, because the product will be accepted by the QFD team only if the consumer's request is satisfied. If the target value and competitive evaluation of the analyzed product are equal, then the scale-up factor is 1, which means that the clients are pleased with the shoes. When the scale-up factor is higher than 1, then the product needs to be improved which means extra efforts for the company.

3. Sales point

Sales points are represented by those features of analyzed product, which are very appreciated by consumers, and are better than competitors'.

The QFD team collaborate with marketing department will assign values from 1 to 2 for each consumer requirement, depending on importance of demand which, in the end, will result in increased sales for the analyzed product.

4. Absolute weight

The formula for calculating the absolute weight is:

The values can be used in the planning process for developing the product. Sometimes the values can be rounded in order to have an easy representation.

5. Prioritizing Requirements – technical design characteristics

It is important to establish the order of priorities about technical design features because it is very useful to understand and decide which one will be developed in the next stages of QFD.

To finish the quality house we have to create four columns for the following elements: technical difficulty degree, target value, absolute weight and relative weight.

Absolute weight = (Relative importance)* (Scale-up Factor)*(Sale point) (1)

6. Technical difficulty degree

Technical difficulty degree assumes setting a level of difficulty for each technical design feature, using a scale from 1 to 10, where 1 represents the minimal difficulty and 10 maximum difficulties. The product improvements costs will be determined based on this evaluation.

7. Target value

Each technical descriptor will receive a target value; this is an objective action which defines the values to be obtained to improve the targeted descriptor. The QFD team establishes the target value so as to reach or exceed consumer value.

To stay on the market the analyzed product should have better features than competitors' product.

8. Absolute weight

For calculation of the absolute weight, the team transforms in numbers the color codes used to indicate the connection between consumer requirements and technical design characteristics. To calculate the absolute weight must sum the products obtained from multiplication of relative importance with the code for each requirement. The formula used is:

Absolute weight = Sum (Value of each connection between consumer requirements and technical design characteristics * Relative Importance) (2)

9. Relative weight

Relative weight is calculated similarly to absolute weight, but indicates bigger values and shows the design area which should be improved. Relative weight takes into consideration information regarding scale-up factor and sale point. Because of this, relative weight shows the impact of technical features on consumer requirements.

CONCLUSIONS

QFD helps companies:

- To highlight consumer needs;
- To identify/find the most significant features of the product and to remove some aspects without affecting sells;
- To design a new product or to redesign an existing one;
- To observe where the company is situated on the market and to compare it with competitors;
- To establish objectives for the technical characteristics that should be in the future.

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EUROPEAN RESEARCH AREA

Co-funded by the Erasmus+ Programme of the European Union

INNOLEA
INNOVATION FOR THE LEATHER INDUSTRY IN JORDAN AND EGYPT

Program: Erasmus+ Capacity Building
Agreement Number: 585822-EPP-1-2017-1-EL-EPPKA2-CBHE-JP
Duration: 36 Months (15.10.2017 – 14.10.2020)

PARTNERS

The **INNOLEA Consortium** was established on the basis of combining the different backgrounds, experience and expertise of the partners. It includes all the skills, recognised expertise and competences required to carry out all aspects of the work programme.

The consortium comprises 12 institutions from 7 countries (Greece, Egypt, Jordan, Italy, Lithuania, Portugal and Romania) representing different parts of Europe and the Mediterranean, presenting thus a balanced geographic coverage. There is a mixture of institutions with different profiles, capacities and complementary competences: private and public higher education institutions, companies and non profit institutions, research and training centres and business associations.

The project Coordinator is National Technical University of Athens (NTUA), Greece. The other partners and ERASMUS+ Grant Beneficiaries are: South Valley University (SVU), Egypt; Arab Academy for Science, Technology and Maritime Transport (AAST), Egypt; Jordan University of Science and Technology (JUST), Jordan; Al-Balqa Applied University (BAU), Jordan; Amman Chamber of Industry (ACI), Jordan; Italian Centre for Permanent Learning (CIAPE), Italy; CREATIVE THINKING DEVELOPMENT (CRE.THI.DEV.), Greece; Technological Centre for the Leather Industry (CTIC), Portugal; "Politehnica" University of Bucharest (UPB), Romania; Kaunas University of Technology (KTU), Lithuania and National Research and Development Institute for Textiles and Leather – Division: Leather and Footwear Research Institute (INCDTP-ICPI), Romania.

AIMS & OBJECTIVES

The leather sectors in Jordan and Egypt comprise mainly semi-industrial companies and small craft-oriented workshops, combining manual and mechanical processes with basic equipment. Only a few large industrial companies exist. 90% of companies of the sector are either small or medium-sized factories or workshops. The sector suffers from a high fragmentation and a lack of quality control in all stages of the value chain. Apart from a couple ones, the vast majority of companies involved in the leather manufacturing supply chain work on highly ineffective and low-quality production techniques using chemicals of low quality and out-dated technology. Moreover, the Jordanian and Egyptian leather industries face the high competition from imported leather products from China that has the advantages of lower production costs as benefits of economy scale.

Furthermore, due to the lack of specialised support, most of the companies of the sector cannot invest in quality, design and innovation and export their products.

There is an urgent need for the sector in the two countries for:

1. Development of competitiveness through lowering production cost, for an increase in productivity, for the development of quality and design and for training in addition to international conformity certification. Quality and innovation are very important for the leather industries in Jordan and Egypt in order to focus on the market segments that need such kind of characteristics.
2. Keeping and increase of local market share and for the development and reliability of the image of the "Made in Jordan" and "Made in Egypt" products.
3. Development of exports to surrounding markets, mainly Arab market, as well as for the exploring of new export opportunities to non-traditional markets such as Europe, Canada and U.S.A. in addition to the African markets.
4. Development and exploring of more niche manufacturing opportunities where the competitive advantage is not mainly price (i.e. specialized products).

The **INNOLEA project aims** at the creation of four leather centres (two in Jordan and two in Egypt) which will play the role of focal points for the leather sector and relevant stakeholders. The services that these centres will offer will be used by companies of the leather sector of the two countries in order to:

- improve the quality and design of their products,
- improve the quality and cost effectiveness of manufacturing techniques and chemicals used,
- be informed about the new fashion trends,
- develop new products,
- learn about requirements for exporting of their products,
- find funding opportunities,
- participate in projects.

This way the leather sector of the two countries will be further developed and become more competitive and export oriented.

Besides the leather sector, the Universities where the leather centres will be established will have the opportunity to expand the fields of their applied research to topics regarding leather.

The staff of the leather centres will be trained by European partners, experts in offering services to the leather sector, gaining, thus, from their experience in setting up and managing this kind of centres.

Specific Objectives:

- ✓ To offer to the leather sectors in Jordan and Egypt access to business development services through the creation of leather centres within the Universities;
- ✓ To promote cooperation between HEIs and businesses through the creation of leather centres within 2 Egyptian and 2 Jordanian universities;
- ✓ To establish other leather centres in other universities;
- ✓ To establish further cooperation between EU and Jordanian & Egyptian Universities and leather businesses.

PROJECT DESCRIPTION

INNOLEA project aims to fill an apparent gap in the area of specialized services for the leather sector with the establishment of four leather centres in local Universities, two in Jordan and two in Egypt utilizing the experience and expertise of EU partners in the area of services for the leather sector. Through the creation of these centres and the further tasks that will be implemented in this project, the leather sectors in Jordan and Egypt will be offered access to business development services, such as quality testing, product certification, training, fashion trends, production organization, BtoB and funding opportunities, and subsequently the Jordanian and Egyptian leathers sector will have a valuable ally for its further development

The INNOLEA project shall approach its methodology with an aim to ensure that the project will be carried out in a disciplined, well managed and consistent manner, one that will ultimately deliver quality project results, on time and within budget.

INNOLEA is a multinational project that will span a period of 3 years. The project comprises a set of implementation activities that will materialise the project objectives, supported by preparation, management, quality and dissemination activities that will ensure the propagation of its results even after the project has ended.

All of the project activities are depicted in a set of **Work Packages and Outputs**, as follows:

WP1 - PREPARATION - Research and state of the art

- Preparation of a Research Report about the local needs and anticipations of the leather sectors in Jordan and Egypt.
- Preparation of a Good Practices database for collaborations between EU and Jordan/Egypt.

The WP1 leader is: JUST

WP2 - DEVELOPMENT - Capacity building and setting up of leather centres

- Capacity building for 16 experts in the EU (4 from each HEI in Jordan and in Egypt) that will staff the Leather Centres
- Establishment of 4 fully operational Leather Centres within HEIs in Jordan and Egypt
- Development of a sustainable business model for the leather centres
- Preparation of brochures about the activities of the Centres
- Development of a collaboration platform between the leather centres

The WP2 leader is: UPB

WP3 - QUALITY & EVALUATION

- Development of a Quality and evaluation Plan
- Sufficient monitoring and quality evaluation of the project through reports every 6 months

The WP3 leader is: CRE.THI.DEV.

WP4 - DISSEMINATION & EXPLOITATION

- Development of a Dissemination and Exploitation Plan
- Development of a Data base for contacts & Mailing list
- Creation of a Project website and online collaterals
- Creation of a Project FB & Twitter
- Preparation of Dissemination material
- Development of a Sustainable business model for the Leather centres
- Preparation of background papers for Roundtables "Leather centres development and Investment promotion for inclusive and sustainable growth in Jordan and Egypt"
- Implementation of Roundtables "Leather centres development and Investment promotion for inclusive and sustainable growth in Jordan and Egypt"
- Preparation of Recommendations based on the results of the Roundtables
- Implementation of the Final conference

The WP4 leader is: CIAPE

WP5 - MANAGEMENT

- Development of a Management Plan
- Monitoring of the project through an interim and a final report;
- Communication and assurance of the progress of the project through face-to-face consortium meetings (7).

The WP5 leader is: NTUA

ENVISAGED RESULTS & TARGET GROUPS

The basic results of the project activities are the establishment of four Leather Centres; 2 at the Jordanian universities (JUST and BAU) and 2 at the Egyptian universities (SVU and AAST).

These centres will play the role of focal points for the leather sector and relevant stakeholders. The services that these centres will offer will be used by companies of the leather sectors in the two countries. This way the leather sectors of the two countries will be further developed and become more competitive and export oriented.

Besides the leather sector, the Universities where the leather centres will be established will have the opportunity to expand the fields of their applied research to topics regarding leather.

The staff of the leather centres will be trained by European partners, experts in offering services to the leather sector, gaining, thus, from their experience in setting up and managing this kind of centres.

The collaboration website platform that will be set up will be a virtual space aiming at favouring collaboration, where, the leather centres and other stakeholders interested in the leather sector will be able to communicate with each other, to be informed about activities, developments and trends, events, projects, funding opportunities, other players, similar institutes or have access to useful links (associations of the leather sector, other Institutes, standardization bodies etc) in the region and worldwide.

Through the dissemination activities and tools (roundtables, database of contacts, project website, brochures, newsletters, recommendations etc.) that will be developed and implemented in the two countries during the project's lifespan, the following target groups will be reached and informed about the project and its outcomes as well as its potential results: Relevant stakeholders such as leather companies, BIOs, policy-makers, training centres, investment promotion agencies, corporate executives and investors, International Finance Institutions providing funds for development, researchers, academics and representatives of civil society.

NEWS AND EVENTS

In order to be permanently informed and to benefit from the project results, please visit our **INNOLEA - Innovation for the Leather Industry in Jordan and Egypt** page at: http://innolea.just.edu.jo

Erasmus+

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INNOLEA PARTNERS

Press Release

LEATHER PRODUCT ENVIRONMENTAL FOOTPRINT CATEGORY RULES OFFICIALLY APPROVED

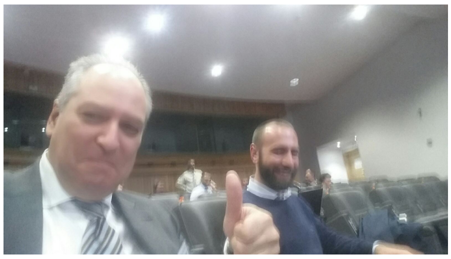
COTANCE

Brussels, 19 April 2018

On 18 April 2018, the Leather Product Environmental Footprint Category Rules (Leather PEFCR) were officially approved by the Environmental Footprint Steering Committee. The establishment of the Leather PEFCR represents a major milestone in coming to a harmonised methodology for the calculation of the environmental footprint of leather made from hides and skins of animals slaughtered for the production of meat, which represents 95%+ of all leathers traded worldwide.

COTANCE Secretary General Gustavo Gonzalez-Quijano: “We will finally see a robust, credible and transparent LCA methodology come to life to accurately and consistently assess our sector’s ecological footprint. Although there is still some “unfinished business” in the PEF methodology, such as the issue of 0-allocation for hides and skins of slaughter animals, the current rules will allow leather manufacturers to demonstrate their capacity to help reduce environmental impacts linked to their production.”

0-allocation to hides and skins, as a by-product of animals slaughtered for meat production, is though fully acknowledged in the CEN Standard EN 16887 (approved in Nov 2016, published in March 2017, applicable not later than Sept 2017) Leather – Environmental footprint – Product Category Rules (PCR) – Carbon footprints. It sets the Product Category Rules for the Carbon Footprint of leather. The PEF looks, however, not only at the issue of Climate Change but addresses also many more environmental impact categories, serving thus the users to get a comprehensive approach for the eco-design of their leathers.



The EF pilot phase will culminate in the EU PEF conference on 23-25 April 2018 after which all approved PEFCRs will be published. A transition phase will follow until 2020, where the lessons of this 4-year Environmental Footprint Pilot Phase will be drawn and possible policy options will be considered. COTANCE will remain involved in the further methodological developments as well as in the policy debate, notably through the “Apparel and Footwear Cluster” that it has promoted and that it will be chairing next to other 6 clusters bringing together the various Product Pilots.

The 2012 UNIDO Report titled Life Cycle Assessment, Carbon Footprint in Leather Processing prepared for and presented by F. Brugnoli during the XVIII Session of UNIDO Leather and Leather Products Industry Panel in Shanghai in 2012, kicked off the work of the leather industry in the area of LCA producing detailed explanations, definitions, methodological approaches and terminology pertaining to leather’s footprint.

COTANCE President Thomas Bee: “Europe’s leather sector can be extremely proud of delivering a comprehensive toolbox after several years of hard work. I would like to thank our Italian colleagues for their leadership role and all member associations and companies that supported the Technical Secretariat of the Leather PEFCR as well as all value chain partners and stakeholders that have supported the process.”

The consortium of the LEAMAN project invites you to take part in the Innovative Leather Product Competition!

The purpose of the Competition is to **promote innovative leather products, services, solutions or technologies and inspire interested stakeholders' creativity**.

Participants to the competition will be asked to share ideas and brainstorm for creating innovative leather products. The ideas of innovative leather products will be voted online. The Competition is open for all interested stakeholders from partners countries: Greece, Italy, Poland, Portugal, Romania and Spain.

The Consortium of the Competition consists of CTIC – Centro Tecnológico das Indústrias do Couro, Alcanena, Portugal - project coordinator; CRE.THI.DEV – Creative Thinking Development, Athens, Greece; CIAPE – Centro Italiano per l'Apprendimento Permanente, Rome, Italy; FPE – Foundation for Promotion of Entrepreneurship, Lodz, Poland; INCDTP-ICPI – National R&D Institute for Textiles and Leather - Division: Leather and Footwear Research Institute, Bucharest, Romania; INESCOP – Instituto Tecnologico del Calzado y Conexas, Alicante, Spain; VC – Virtual Campus Lda, Porto, Portugal. Foundation for Promotion of Entrepreneurship will run the Competition on behalf of the partners.

Participants are required to submit their submissions based on the **application forms** (stage 1) via the Virtual Challenge Community platform and prepare **business plans** (stage 2) and **presentations** on VCC platform and on partners websites (stage 3) before the due date on **15.06.2018** for submission online. Stage 4 includes **online voting** for the best ideas and will take place between **16-30.06.2018**. Three projects with the highest score will be awarded. Stage 5 concerns announcement of the results at the meeting in Poland on 5.07.2018 and on partners websites and VCC platform. In stage 6 **three of the best projects will be submitted to Indiegogo.com platform for crowdfunding**.

For more details regarding competition rules, please visit **http://leaman.eu/competition/**.

NATIONAL AND INTERNATIONAL EVENTS

THE 34TH INTERNATIONAL CONFERENCE ON SOLID WASTE TECHNOLOGY AND MANAGEMENT MARCH 31-APRIL 3, 2019, ANNAPOLIS, MARYLAND, U.S.A.

The 34th International Conference on Solid Waste Technology and Management will be held in Annapolis, Maryland, U.S.A. on March 31-April 3, 2019. Participants are expected from over 40 countries.

Researchers, educators, government officials, consultants, managers, community leaders and others with expertise in solid waste are invited to submit papers for oral presentation or poster session at the Conference.

Papers related to all aspects of solid waste technology and management are of interest. Abstracts should be submitted on-line at: http://solid-waste.org/. The deadline for submission of abstracts is **October 31, 2018**. Early submission is encouraged.

More information: http://solid-waste.org/

4TH INTERNATIONAL CONGRESS ON WATER, WASTE AND ENERGY MANAGEMENT 18-20 JULY 2018, MADRID, SPAIN

4TH INTERNATIONAL CONFERENCE ON GREEN CHEMISTRY AND SUSTAINABLE ENGINEERING 23-25 JULY 2018, MADRID, SPAIN

The 4th International Conferences are organized by academics and researchers belonging to the University Complutense of Madrid (UCM), University Carlos III of Madrid (UC3), University of Extremadura (UEx) and University of Las Palmas de Gran Canaria (ULPGC) with the technical support of Sciknowledge European Conferences.

These events will include the participation of renowned keynote speakers, oral presentations, posters sessions and technical conferences related to the topics dealt with in the Scientific Program as well as an attractive social and cultural program.

The papers will be published in the Abstracts E-book of the Conference. Those communications considered of having enough quality can be further considered for publication in International Conference Journals. At the authors' choice, those works not suitable for publication in any of the congress journals will be published in the Extended Proceedings E-book of the International Congress.

Deadlines:

- Abstracts sending: **May 1st 2018**
- Acceptance notification: **May 15th 2018**
- Submission of extended abstracts (optional): **May 30th 2018**
- Early bird registration: **May 30th 2018**

More information: http://greenchemistry18.com, http://waterwaste18.com

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Presentation of Papers

The scientific papers should be presented for publishing in English only. The text of the article should be clear and precise, as short as possible to make it understandable. As a rule, the paper should not exceed fifteen pages, including figures, drawings and tables. The paper should be divided into heads and chapters in a logical sequence. Manuscripts must meet high scientific and technical standards. All manuscripts must be typewritten using MS Office facilities, single spaced on white A4 standard paper (210 x 297 mm) in 11-point Times New Roman (TNR) font.

Paper Format

Title. Title (Centered, 12 pt. TNR font) should be short and informative. It should describe the contents fully but concisely without the use of abbreviations.

Authors. The complete, unabbreviated names should be given (Centered, 10 pt. TNR font), along with the affiliation (institution), city, country and email address (Centered, 9 pt. TNR font). The author to whom the correspondence should be addressed should be indicated, as well as email and full postal address.

Abstract: A short abstract in a single paragraph of no more than 200-250 words must accompany each manuscript (8 pt. TNR font). The abstract should briefly describe the content and results of the paper and should not contain any references.

Keywords. Authors should give 3-5 keywords.

Text

Introduction. Should include the aims of the study and results from previous notable studies.

Materials and Methods. Experimental methods should be described clearly and briefly.

Results and Discussions. This section may be separated into two parts. Unnecessary repetition should be avoided.

Conclusions. The general results of the research are discussed in this section.

Acknowledgements. Should be as short as possible.

References. Must be numbered in the paper, and listed in the order in which they appear.

Diagrams, Figures and Photographs should be constructed so as to be easy to understand and should be named "Figures"; their titles should be given below the Figure itself. The figures should be placed immediately near (after or before) the reference that is being made to them in the text. Figures should be referred to by numbers, and not by the expressions "below" or "above". The number of figures should be kept to minimum (maximum 10 figures per paper).

Tables. Should be numbered consecutively throughout the paper. Their titles must be centered at the top of the tables (12 pt. TNR font). The tables text should be 9 pt. TNR font. Their dimensions should correspond to the format of the Journal page. Tables will hold only the horizontal lines defining the row heading and the final table line. The tables should be placed immediately near (after or before) the reference that is being made to them in the text. Tables should be referred to by numbers, and not by the expressions "below" or "above". The measure units (expressed in International Measuring Systems) must be explicitly presented.

Formulas, Equations and Chemical Reactions should be numbered by Arabic numbers in round brackets, in order of appearance, and should be centered. The literal part of formulas should be in Italics. Formulas should be referred to by Arabic numbers in round brackets.

Nomenclature. Should be adequate and consistent throughout the paper, should conform as much as possible to the rules for Chemistry nomenclature. It is preferable to use the name of the substances instead of the chemical formulas in the text.

References should be numbered consecutively throughout the paper in order of citation in square brackets; the references should list recent literature also. Footnotes are not allowed. If the cited literature is in other language than English, the English translation of the title should be provided, followed by the original language in round brackets. Example: Handbook of Chemical Engineer (in Romanian), vol. 2, Technical Press, Bucharest, 1951, 87.

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