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CHARLES UNIVERSITY IN PRAGUE,
FACULTY OF PHYSICAL EDUCATION AND SPORT,
DEPARTMENT OF ANATOMY AND BIOMECHANICS[1]
DEPARTMENT OF TECHNICAL AND COMBAT SPORTS AND MARTIAL ARTS[2]

THE INFLUENCE OF MORFOLOGICAL SHAPE OF FOOT ON DYNAMIC LOADING FORCES EXERTED ON SOLE OF THE FOOT DURING ICE-HOCKEY SKATING

PETR ŠŤASTNÝ[1] , PETR KUBOVÝ[1], FRANTIŠEK LOPOT[1],
KAREL JELEN[1], MILOŠ FIALA[2]

SUMMARY

The influence of morphological shape of the foot on dynamic loading forces was demonstrated in many studies (Morton, 1937; Kolář, 2006; Moriyasu and Nishiwaki 2009). But it has never been specifically studied during ice hockey skating. Loading forces were investigated during ice hockey skating, but not in the contend a shape of the foot, but rather in contend the techniques of skating and push off strength (Kho, 1996; Pearsall, Turcotte et al., 2000). It is normally considered that the shape of foot is the basic factor determining the ground reaction forces (GRF) (Nigg, Segesser, et al., 1992; Kolář, 2006). The Laboratory of Extreme Loading (BEZ) has been designed and validated device for measuring GRF during skating. Using this newly established device was done a pilot study exploring the relationship between morphological shape of the foot and the loading forces. As a morphological shape of a foot was rated the length ratio between first and second finger and the length ratio of first and third finger (phalanges length and metatarsophalanges length) to dynamics of loading force component F_t, bending force components F_o and point acting of the force on the skate blade – **x** during forward skating. The results were determined based on the correlation variables as the basis for further experiments. In a pilot study has been demonstrated the interdependence of two foot shape characteristics with dynamic of the loading forces, both dependencies were demonstrated for the first and third metatarsophalanges ratio. Specifically, it was showed the dependency with first and third metatarsophalanges ratio to the moment of maximum loading force F_t, when the statistical significance level of p = 0.03 found concordance $\tau_r = 0.79$. In metatarsophalanges ratio of first and third finger was observed on the significance level of p = 0.02 the discordance $\tau_r = -0.79$ with the average position of the point of action of the force on skate blade – **x**.

Key worlds: dynamometric, measuring skates, shape of the foot, loading forces, forward skating

INTRODUCTION

Ice hockey players are taking the health risks due to injury or pressure sores caused by wearing hockey gear and equipment, mainly skating boots (Pearsall, Turcotte et al., 2000). Wearing the skates has an extreme danger by starting the tissue remodeling of feet due to long-term extreme loads. Currently is not sufficiently clarified the cause of discomfort in ice-hockey skates, but is verified that the shape characteristic of foot significantly affects the interaction of foot-skates-surface system (Dewan, 2004).

Morphological structure affects the foot function, which the authors regarded as Riegerova (Riegerová, 2006) and Kucera (Kučera, Korbelář et al., 1994) mean as a fundamental basis for the distribution of plantar pressures on the foot. These are many studies dealing with the relationship between the proportional dimensions of soles of the foot with specific deformations (Jelen 2007, Kolář, Jelen 2006).

Morphological structure is evaluated according to the relative proportions of the phalanges and metatarsals (Fig. 1), where we distinguish three morphological types of feet: the Egyptian foot, Square (wide) foot and Antic foot sometimes referred as Greco-Roman (Eltze, Miller et al., 1993; Kučera, Korbelář et al., 1994; Riegerová 2006). For

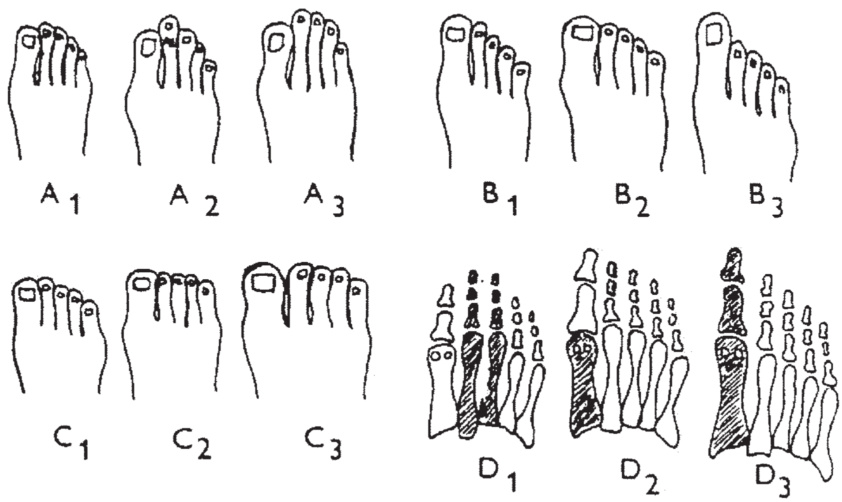

Figure 1. Morphological types of foot

Legend:
A1, A2 common types of Antic foot
A3 Antique type with unusually long fingers
B1, B2 common types of Egyptian foot
B3 long big toe at the Egyptian foot
C1, C2 common types of Square foot
C3 Square foot with hypertrophy of small fingers
D1 metatarsophalangeal predominance type of ancient feet
D2 short first metatarsal at the Egyptian type
D3 metatarsophalangeal preponderance of a big toe at the Egyptian type .
Picture by (Kučera, Korbelář et al. 1994).

research evaluation of interactions between foot shape and skating boots seems to be this kind of evaluation of the shape of limbs as well as the most practical.

Antic foot (fig. A1) (sometimes referred to Greco-Roman) is characterized by significantly lower tactile surface. Contact area, unlike the Egyptian foot of the half, but this kind of foot has a predisposition to high performance. However, requires careful selection of form of the load. Dominating parts are the second and third finger, where is the peak load in the force transition during most of movements.

Egyptian foot (fig. B1) is characterized by a large touch area of fingers and minimal risk of overloading the local elements supporting the foot. Due to the anatomical structure has the greatest ability to distribute the load. Touch line goes from the dominant big toe up to the fourth finger, while the fifth does not remain outside the function. From a sports point of view is this most convenient type of conditions for both dynamic and static types of loads.

Square foot (fig. C1) is the least functional in terms of performance and prognostic. Locomotion of all types is difficult especially for mechanical overload and severe painful response. The first three fingers are aligned, which apparently meant a relatively large touch zone. But in this case, unlike the previous system, the fingers are not working together, but isolated.

The relationship between morphological characteristics of the foot and the dynamic of loading forces may be assessed using a special device "measuring skate" that is able to detect the loading force, bending force and point of action of the force on the skate blade (Šťastný, Kubový et al. 2010).

In ice hockey is an elementary movement the slide on ice with push off when skating forward (Pavliš 2000). In the pilot study was important to record those elementary movements, which following to each other during forward skating.

METHODS

The aim was to design a pilot study using an experimental measuring device, "measurement skates". The basics of pilot project were a case study of loading forces related to morphological characteristics of the loaded foot. Towards these goals was posed the scientific question:

Is it possible to propose solutions from pilot study that are starting points for further experimentation based on the analysis of shape characteristics of the foot and dynamics the loading forces?

This scientific question comes from the fact that presently can not be accurately predicted to what is influenced by the specific characteristics of individual foot. The work, however, does not aim to uncover a direct relationship between foot deformities and the use of skate shoes, but found a combination of methods to determine these relationships after the quantitative research of larger number of subject. There is therefore complementary scientific question:

Which forces in system foot-skates-surface is important to record for determining the relationship between morphology and dynamic loading of the foot?

The null hypothesis (H1) was based on the assumption that a time constant characteristic of foot will be the basis for a dynamic course of loading forces.

H1: morphological structure of the foot predicts the dynamics of F_o and F_t acting on the sole of the foot in ice-hockey skates.

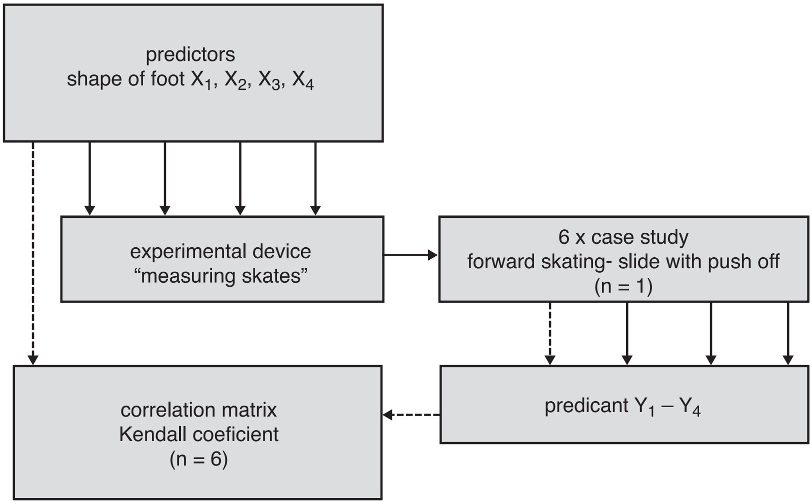

Figure 2. Scheme of pilot study

Legend:
n = numbres of subject, X_1–X_4 = predictors, Y_1–Y_4 = predicants, arrows indicates data processing.

Morphological structure represented by phalanges and metatarsophalanges ratio of first and third finger predicts the dynamic loading in system foot-skates-surface.

As a loading force is considered an interaction force component F_t on the beam of skate's blade, bending component of interaction forces F_o on the blade and point of action of the force on the skate's blade. The pilot study was done by finding out the time-constant predictors X_1–X_4, which were characterizing the morphological shape of the foot. Then, using the "measuring skate" were measured dynamic forces, designated as Y_1–Y_4 predicants during slide with the push off. After determining the predicant value in six case studies were predictors and predicant tested for interdependence by Kendall correlation coefficient (Fig. 2).

Initial independent variables were measured from foot roentgen (RTG) taken with the informed consent of players (Fig. 3). Detected variables were:

X_1 – length ratio of a big toe and second finger (mm/mm = coefficient) (1)
X_2 – length ratio of a big toe and third finger (mm/mm = coefficient) (2)
X_3 – metatarsophalanges length ratio of a big toe and second finger (mm/mm = coefficient) (3)
X_4 – metatarsophalanges length ratio of a big toe and third finger (mm/mm = coefficient) (4)

As independent variables were determined the predicants of extreme values of measured forces and the average position of the point of action of the force:
Y_1 – extreme value F_t momentum (phase of movement in %)
Y_2 – positive value of F_o momentum (phase of movement in %)
Y_3 – negative value of F_o momentum (phase of movement in %)
Y_4 – average the point of action of the force (% of the blade length)

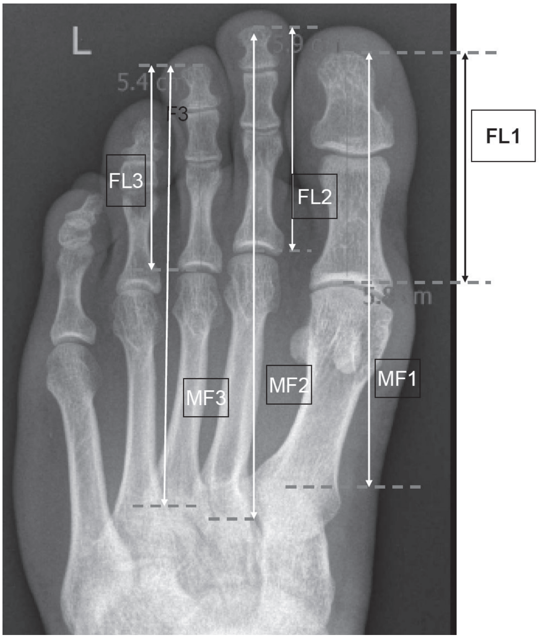

Figure 3. Graphic of findings the X_1–X_4

X_1 = FL1/FL2 (1)
X_2 = FL1/FL3 (2)
X_3 = MF1/MF2 (3)
X_4 = MF1/MF3 (4)

Legend:
Phalanges and metatarsophalanges length and their ratio.
FL1 = phalanges length of big toe, FL2 = phalanges length of second finger, FL3 = phalanges length of third finger, MF1 = metatarsophalanges length of big toe, MF2 = metatarsophalanges length of second finger, MF3 = metatarsophalanges length of third finger, X_1–X_4 = predicors. Phalanges length is determined by a direct distance of the center base of the proximal joint connection of phalanges article and distal tip of the distal phalang head. Metatarsophalanges length is determined by a direct distance of the center base of the proximal joint connection of metatars article and distal tip of the distal phalang head.

Tested group was the representative sample of six ice hockey players. A selected player has at least 15 years long history of ice-hockey playing and they were current active ice hockey players.

Due to the fact that our aim was a verifying the measuring system, the skating technique and performance achieved by player were not a determining factor in choosing player for our study. Measured player had booted “measuring” skate on the left leg, and the same pair of skates on the right leg, which was the same weight and shape. Camera was performed 2D kinematic record of the ongoing movement.

Instructions to players were: “After the start, using forward skating executes several aggressive push offs”. The evaluated movement was a slide with **push off**. For each

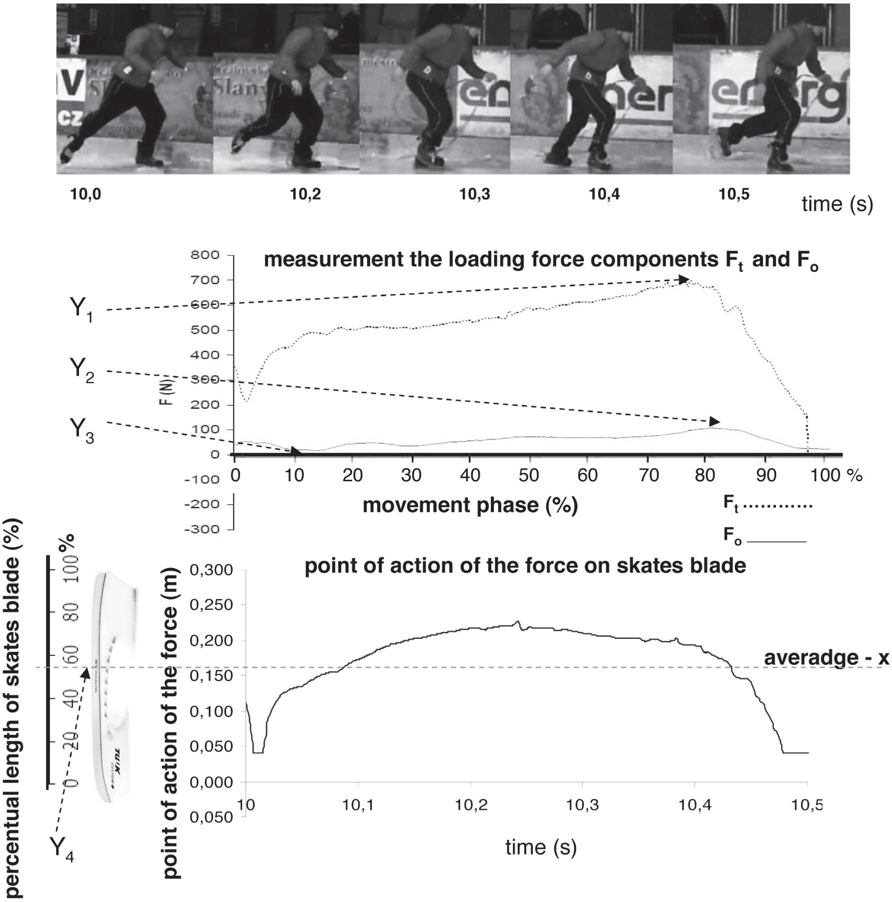

Figure 4. Graphical display of described predicants

Legend:
Main picture shows the kinogram of slide with push off during skating forward. Graph shows the measurement of loading force components F_t and the F_o. Graph "point of force action on blade" shows the dynamic progress of the point of force vectors on blade of skates – x. Y_1 – moment of extreme value the F_t (phase of movement in %), Y_2 – moment of extreme positive value of F_o (phase of movement in %), Y_3 – moment of negative extreme value of F_o (phase of movement in), Y_4 – average of point of action of the force (% from calibrated part of a blade).

player were performed three measurements in one day, and three measurements next week. The average of six measurements entered in the evaluation of experiment.

For each measurement was assessed a slide with push off of the left foot, which was always chosen a movement that was performed at the stage when the player skated by stable cyclic motion. As the beginning of the slide was considered a moment of complete lay down a skate on the left foot during the "skating step" (Fig. 4 kinogram time 10.00 s).

As the end of movement was considered the moment when the left skate has lost contact with the ice (Fig. 4 kinogram time, 10.50 s).

RESULTS

Players were identified by monograms. After that were made the X-ray image of players left foot from which were determined the predictors X_1–X_4 (Tab. 1). During the experiment was one player measured six time during forward skating. Then were determined the values of Y_1–Y_4 for each measurement separately, after that was calculated the Y_1–Y_4 as average value of six measurement (Tab. 2). For tests carried out in different days was also determined the test re-test reliability by coefficient of variability v_x. Average values of Y_1–Y_4 then entered into kros-correlation matrix, where they were evaluated against predictors X_1–X_4. The input data of all probands shows Tab. 3.

Table 1. Predictors of player HH

	FL1	**FL2**	**FL3**	**MF1**	**MF2**	**MF3**
l (mm)	57	54	57	142	138	136
FL1/FL1, FL2, FL3 (mm/mm)	1.00	1.06	1.04	———	———	———
MF1/MF1–MF3 (mm/mm)	———	———	———	1.00	1.03	1.04
X_1	**1.06**					
X_2	**1.00**					
X_3	**1.03**					
X_4	**1.04**					

Legend: Phalanges and metatarsophalanges length and their ratio.
FL1 = phalanges length of big toe, FL2 = phalanges length of second finger, FL3 = phalanges length of third finger, MF1 = metatarsophalanges length of big toe, MF2 = metatarsophalanges length of second finger, MF3 = metatarsophalanges length of third finger, X_1–X_4 = predicors.

Table 2. Predicant measured by experimental device during slide with push off on player HH

Predicants	**measurement**						**∑**	**$\bar{x}$**	**S_x**	**1/4 S_x**	**v_x**
	1	**2**	**3**	**4**	**5**	**6**	**%**	**%**			**%**
Y_1	79	77	81	77	73	71	457,9	76.3	3.5	0.9	4.6
Y_2	93	86	98	91	88	87	543,0	90.5	4.1	1.0	4.5
Y_3	36	40	23	25	34	31	189,1	31.5	6.0	1.5	19.2
Y_4	49	50	51	49	49	50	299,3	49.9	0.8	0.2	1.7

Legend:
Results from six measurements of Y_1–Y_4. Measurement 1–3 ordered in lines was done first, Measurement 4–6 ordered in lines was done with 14 days time distance, ∑ = sum, = average, S_x = standard deviation, ¼ S_x = quarter standard deviation, v_x = coefficient of variability. Averadge value is final Y_1–Y_4 for measured player.

The results from individual case analysis were tested for predictive validity X_1–X_4 with average values of Y_1–Y_4. Test scores of the input variables X and output dependent variables Y are shown in tab. 4.

Table 3. Summary of predictors and the resulting predictants during slide with push off

player	X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4
	FL1/FL2	FL1/FL3	MF1/MF2	MF1/MF3	Ft	Fo+	Fo–	x
	mm/mm	mm/mm	mm/mm	mm/mm	(%)	(%)	(%)	(%)
JS	1.06	1.00	1.03	1.04	76	90	32	50
HH	1.10	1.04	1.03	1.04	83	78	42	45
VL	1.20	1.20	1.00	1.05	84	82	17	35
JJ	1.37	1.31	1.06	1.06	84	82	8	32
SS	1.00	1.13	0.96	1.08	86	79	12	34
TT	1.02	1.05	0.95	1.02	81	82	15	52
	1.13	1.12	1.01	1.05	82.3	82.2	21.0	41.3
S_x	0.13	0.11	0.04	0.02	3.2	3.8	12.0	8.0

Legend:
= average, S_x = standard deviation, FL1 = phalanges length of big toe, FL2 = phalanges length of second finger, FL3 = phalanges length of third finger, MF1 = metatarsophalanges length of big toe, MF2 = metatarsophalanges length of second finger, MF3 = metatarsophalanges length of third finger, X_1–X_4 = predicors

Table 4. Correlation matrix of mutual validity of input and output variables identified from the average values measured during slide with push off.
The correlation coefficient (τ_r) was determined only when the level of significance (p) was less than 5% ($p < 0.05$).

		X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4
		FL1/FL2	FL1/FL3	MF1/MF2	MF1/MF3	Ft	Fo	Fo	x
X1	τr	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
X1	p	x	0.35	0.13	0.44	0.70	0.69	0.85	0.19
X2	τr	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
X2	p	0.35	x	0.70	0.25	0.13	1.00	0.09	0.09
X3	τr	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
X3	p	0.13	0.70	x	0.70	0.85	0.84	0.70	0.44
X4	τr	0.00	0.00	0.00	1.00	0.79	0.00	0.00	–0.83
X4	p	0.44	0.25	0.70	x	0.03	0.54	0.25	0.02

Legend:
X_1–X_4 predictors, Y_1–Y_4 predicants, τ_r = Kendall correlation coefficient, p = level of significance, by bold letters are written the significant interdependence of foot shape to predictors. If hight correlation coefficient **was find out, the correlation had value of 0!** FL1 = phalanges length of big toe, FL2 = phalanges length of second finger, FL3 = phalanges length of third finger, MF1 = metatarzophalanges length of big toe, MF2 = metatarzophalanges length of second finger, MF3 = metatarzophalanges length of third finger, X_1–X_4 = predicors, Y_1–Y_4 = predicants.

By analysis of test scores of independent variables – predictors X_1–X_4 (Table 3) can be determined that the detected phalanges and metatarsophalanges ratio are different. Average for phalanges ratios is X_1 = 1.13 and X_2 = 1.12 and average for metatarsophalanges ratio is X_4 = 1.01, X_3 = 1.05. From these differences could be expected also different predictive validation.

From the correlation matrix can be seen that into the two interdependances were found significant relations satisfying the conditions required to confirm hypotheses H1. Both significant coefficients are shown in the predictor X_4. It was thus demonstrated the dependency between shaped characteristics of the foot and dynamics of loading forces on the foot. Metatarsophalanges ratio of the first and third finger can be considered as a strong predictor.

Parameters of loading forces on the skates correlated positively in predictor X_4 and predicant Y_1 with τ_r = 0.79 p = 0.03. From this proven concordances can be argued that what is the relative length of the metatarsophalanges first finger to the third finger bigger, the later the maximum of F_t occur. It is thus allow a longer period for the production of force that is largely being implemented by F_t component.

Parameters of loading forces on the skates correlated negatively in predictor X_4 and predicant Y_4 with τ_r = −0.83 p = 0.02 during the slide with the push off. From this proven discordance can be argued that what is the relative length of the metatarsophalanges first finger lower to the third finger, the more it will be point of action of the force under the front beam of the skate blade. Proportionately smaller first finger will move more of the point of action of the force on front of the skate blade.

DISCUSSION

This study is in the general concept focused on biomechanics measurement the performance and health aspects of long-term specific sporting activities. In field of ice-hockey is extensively developed the theme of laterality and physiology of human movement. The issue of foot, and generally dealing with new solutions is happening primarily by manufacturers of skate's shoes.

The aim was to design a pilot study using experimental measuring equipment, "measurement skates" and case analysis of loading phenomenon related to morphological characteristics of the loaded foot. The main result is that by measuring the loading forces components and point of action of the force on skate blade we can assess the interdependence between shape of foot and the dynamic loading forces.

In a pilot study were critically evaluate the selected variables X_1–X_4 and Y_1–Y_4. For a possible quantification and interpretation of results it was necessary to reduce the number of variables empirically based on theoretical analysis. We consider Selected variables as fundamental for the dynamic forces description, such as determining the shape of foot, which were evaluated by phalanges metatarsophalanges ratios between first, second and third finger. Foot characteristic was itself a fundamental criterion for determining the shape of foot according to Eltzeho (Eltze, Miller et al. 1993). There are more ways how to determine the shape of foot. It could be evaluated by the angle of Smirak, Clark or evaluation by Godunov. For our purposes, it was necessary to select a methodology to determine ontogenetic immutable characteristic of the foot.

The study used correlation coefficient, which in essence did not determine statistical significance (as the correlation coefficient is), but only showed the possibility of finding dependencies. For these purposes it was choose the Kendall correlation coefficient τ, which makes no assumption about the nature of probability distribution and can handle any number of individual results.

We consider the measurement the F_o–F_t as elemental for detection of loading parameters for future research, but it is not clear if other characteristic like "plantar pressures" could have better predictive value. Both components of force appear to be very detailed description of the characteristics the interaction in system foot-skate-surface (Fig. 2). In next research will be possible to compare the dynamic course of this forces and not only one choose extreme value. Moreover, it is possible to monitor dynamic changes in the forces due to change in slope of skates or modify the inner material.

From biomechanical point of view is very important to find out the loading force vector F_t acting between foot and skate and bending force vector F_o acting perpendicularly to line of skates blade (Dewan 2004). Same importance we find out for a point of acting of the force on skates blade, because for this parameter was proven the direct relation to shape characteristic of the foot. Point in which the force act is a parameter which influe the push off. In contend of length of big toe and position the point of action of the force is possible to change of sole slide or shape of the blade holders in dependance on parcial length the first and third foot fingers. The effectivity of those changes could be prove in following quantitative study.

CONCLUSION

By the results of the study was confirmed hypothesis H1, which assumed that the morphological shape of the foot predicts the loading forces. They were shown two interdependent variables tested by Kendall correlation coefficient, which confirmed this hypothesis. They were recognized interdependence between metatarsophalanges ratio of first and third finger in concordance with the moment of maximum loading force component F_t(τ_{r-}= 0.79; p = 0.03) during slide with push off. For metatarsophalanges ratio of first and third finger was on the significance level of $p = 0.02$ observed also discordance $\tau_r = -0.79$ with the average position of point of action of the force on skate blade – x. The metatarsophalanges length ratio of the first and third finger was proved to be a strong predictor for at least two loading characteristics.

The scientific question has been positively answered. The characteristic the shape of the foot were related to dynamics of loading forces. These relations propose solutions that are starting points for further experiments. For further quantitative research is known how to design targeted experiments that have scientific relevance. The two main directions for future research is the monitoring of changes in the loading forces due to changes in shoes conditions and quantification of optimum load for different types of foot shapes. Measurement of loading forces on the beam of skates has proved to be an accurate identifier of the interaction of foot-skates-surface.

LIST OF ABBREVIATIONS

$\sum$	suma
¼ S_x	quater of standard deviation
2D	two dimension
BEZ	biomechanics of extreme loading
FL	phalangeal length of fingers
F_t	load-bearing force
F_o	bending force
GRF	ground reaction forces
MF	methatarzophalangeal length of fingers
l	length
p	level of significance
S_x	standard deviation
τ_k	Kendall coeficient
v_x	coeficient of variation
X_1–X_4	predictors
Y_1–Y_4	predictants
x	space vector, point action of the force average

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REFERENCES

DEWAN, C. (2004). *Biomechanics of the foot and ankle during ice hockey skating*, Department of Kinesiology and Physical Education McGill University Montreal, Quebec, McGill University. Masters of Science, 164.

ELTZE, J., MILLER N., et al. (1993). *Die Verordnung orthopadischer Zurichtungen am Konfektionsschuh und am ortho-padischen Aufbauschuh*. Deutsch–Öesterreich–Schweiz. Orthop. Kongress. Grafeling Demeter Verlag.

JELEN, K. a kol. (2007). Otisk nohy: Tvarová rekonstrukce a nelineární model distribuce tlaku. *Pohybové ústrojí*, 14(3–4), pp. 370–373.

KOLÁŘ, V., JELEN, K. (2006). Interakční dynamika nohy s ortopedickou vadou při kontaktu s podložkou. In Otáhal, S. et al. *Biomechanics, biofluidics and alternative biomaterial substitutions. Biomechanika, biofluidika a alternativní biomateriálové náhrady.* 1st ed. Praha: Charles University in Prague, FTVS, 48, p. 107.

KHO, M. E. (1996). *Bone-on-bone forces on ankle and knee in figure skaters during loops jumps: clinical implication*. Waterloo, Ontario, Canada.

KOLÁŘ, V. (2006). *Interakční dynamika nohy s deformitou hallux valgus při kontaktu s podložkou*. Fakulta tělesné výchovy a sportu. Praha, Univerzita Karlova (Praha), 70.

KUČERA, M., KORBELÁŘ, P., et al. (1994). "*Noha – jeden z limitujících faktorů výkonnosti.*" Med Sport Boh Slov, 3, pp. 114–119.

MORIYASU, K. NISHIWAKI, T. (2009). *Measurement technique of GRF components distribution in running*, Taylor & Francis 1, pp. 109–111.

MORTON, D. J. (1937). *Foot disorders in general practice*, Journal of the American Medical Association, 109, pp. 1112–1119.
NIGG, B., SEGESSER, B., et al. (1992) *Biomechanical and orthopedic concepts in sport shoe construction*, Medical Science Sports Exercise, 24, pp. 595–602.
PAVLIŠ, Z. (2000) *Abeceda hokejového bruslení*, Český svaz ledního hokeje, Praha.
PEARSALL, D. J., TURCOTTE R. A. et al. (2000). *Biomechanics of ice hockey*, Philladelphia, Lippincott Williams & Wilkins.
RIEGEROVÁ, J. (2006). *Aplikace fyzické antropologie v tělesné výchově a sportu*. Hanex, Olomouc.
ŠŤASTNÝ, P., KUBOVÝ P., LOPOT F., JELEN K. (2010). The detection of loading forces exerted on he skate and sole of the foot during skating, Acta Gymnica Carolinae-kinantropologica, 46(2), pp. 55–67.

VLIV MORFOLOGICKÉHO TVARU NOHY NA DYNAMIKU ZÁTĚŽOVÝCH SIL PŮSOBÍCÍCH NA PLOSKU NOHY BĚHEM BRUSLENÍ V LEDNÍM HOKEJI

PETR ŠŤASTNÝ, PETR KUBOVÝ, FRANTIŠEK LOPOT,
KAREL JELEN, MILOŠ FIALA

SOUHRN

Vliv morfologického tvaru nohy na dynamiku zátěžových sil je prokázán v mnoha studiích (Morton 1937; Kolář 2006; Moriyasu and Nishiwaki 2009). V ledním hokeji zatím nebyl vliv morfologické struktury na dynamiku zátěžových sil cíleně zkoumán. Byly sice zkoumány zátěžové síly během bruslení, nikoliv však v kontextu tvaru nohy, ale spíše techniky bruslení a síly odrazu (Kho 1996; Pearsall, Turcotte et al. 2000). Běžně je považován tvar obuvi a případné deformace nohy za základní faktor určující reakční síly podložky (GRF) (Nigg, Segesser et al. 1992; Kolář 2006). V laboratoři biomechaniky extrémních zátěží (BEZ) bylo konstruováno a validizováno zařízení umožňující měřit GRF během bruslení. S využitím tohoto nově zavedeného zařízení byla provedena pilotní studie zkoumající právě vztah morfologického tvaru nohy a průběhu zátěžových sil na noze. Z morfologického tvaru nohy byl hodnocen poměr délky prvního a druhého prstu a poměr délky prvního a třetího prstu (délka falangeální a metatarzofalangeální) vůči průběhu zátěžové složky síly F_t, ohybové složky síly F_o a působišti síly na noži brusle-x během bruslení vpřed. Z výsledků byly určeny korelační závislosti sledovaných proměnných a východiska pro další experimenty. V pilotní studii byly prokázány dvě vzájemné závislosti tvarových charakteristik nohy s dynamickým průběhem zátěžových sil, přičemž obě závislosti byly prokázány pro metatarzofalangeální poměr prvního a třetího prstu. Konkrétně šlo o vzájemnou závislost metatarzofalangeálního poměru prvního a třetího prstu vůči momentu maximální hodnoty zátěžové síly F_t během skluzu s odrazem, kdy byla na statistické hladině významnosti $p = 0.03$ zjištěna konkordance $\tau_r = 0.79$. Pro metatarzální poměr prvního a druhého prstu byla na hladině významnosti $p = 0.02$ zjištěna diskordance $\tau_r = -0.79$ s polohou průměrné hodnoty působiště síly na noži brusle x.

Klíčová slova: dynamometrie, měřící brusle, tvar nohy, zátěžové síly, bruslení

Petr Šťastný
petakena@seznam.cz