

# Investigation of the Effect of Skate-Use on the Sole Contact Areas and Maximal Forces of Ice Hockey Players

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## ABSTRACT

The aim of the present study was to compare the pedobarographic parameters of contact areas and maximal forces for 11 contact areas of foot-soles in professional male Ice hockey players and healthy people and to investigate the effect of Ice hockey on the foot-sole. The study consisted of 22 Ice hockey players without any foot-related complaints and as the control group, 25 male volunteers. EMED-SF plantar pressure analysis system was used in the study. Any statistically significant difference between the averages of the study and the control groups was examined using non-parametrical Mann Whitney U test and the extent of the linear relationship between the physical structure and the variables of the foot-sole was examined by calculating the Pearson ( $r$ ) coefficient. According to these results and after the measurements on foot-sole variables and the sports done by the ice hockey players; a significant difference between right foot heel lateral and left foot 4<sup>th</sup> metatarsus head in terms of 11 contact areas. As for the maximal forces of the contact areas; it was found out that the difference between left foot total, 2<sup>th</sup> metatarsus head and pollex was found to be significant ( $P<0.01-0.05$ ). As a result; ice hockey caused some changes in contact areas of the foot-sole and maximal forces of the contact areas, but it did not cause big damages for the foot-sole. It was particularly seen that shoes worn were partly successful in supporting and protecting foot-sole. As the result of these conclusions; it was concluded that ice hockey did not cause such a serious damage to foot-sole of the players to require medical interventions.

**Key Words:** Sole, contact areas, maximal forces, hockey, pedobarographic.

## Buz Hokeyi Sporunun Ayak Tabanı Temas Alanı ve Maksimal Kuvvete Etkisinin İncelenmesi

### ÖZET

Bu çalışmanın amacı profesyonel buz hokeyi sporcularıyla sağlıklı bireylerin ayak tabanı maksimal kuvvet ve temas alanları pedobarografik değerleri incelenerek buz hokeyi sporunun ayak tabanına etkisi araştırılmıştır. Çalışmaya 22 buz hokeyi sporcusu ve 25 sağlıklı gönüllü katılmıştır. Çalışma EMED-SF (Novel GmbH, Münih, Almanya) plantar basınç analiz sistemi kullanılarak yapılmıştır. Denek ve kontrol grubunun iki ölçümünün ortalamaları alınarak, ortalamalar arasında istatistiksel olarak anlamlı farkın olup olmadığı non-parametrik Mann Whitney U testi, fiziksel yapı ve ayak tabanına ait değişkenler arasındaki doğrusal ilişkinin büyüklüğü Pearson'un ( $r$ ) katsayısı hesaplanarak incelenmiştir. Bulgulara göre buz hokeyicilerin yaptıkları spor ile ayak tabanına ait değişkenler arasındaki ölçümler sonunda ayak tabanı 11 temas alanlarında sağ ayak topuk laterali ve sol ayak 4. metatars başında farklılıklar önemli bulunmuştur. Temas alanı maksimal kuvvetlerde ise sol ayak total, 2. metatars başı ve ayak başparmağında farklılığın anlamlı olduğu tespit edilmiştir ( $P<0.01-0.05$ ). Sonuç olarak buz hokeyi sporunun ayak tabanının temas alanları ve temas alanlarındaki maksimal kuvvetlerinde bazı değişime neden olduğu ancak ayak tabanına genel anlamda büyük zararlara neden olmadığı görülmektedir. Özellikle kullandıkları ayakkabıların ayak tabanını destekleme ve koruma konusunda kısmi başarılı olduğu tespit edilmiştir. Bu çıkarımlar sonucunda buz hokeyi sporunun sporcuların ayak tabanlarında tıbbi müdahaleleri gerektirecek bir değişime neden olmadığı sonucuna varılmıştır.

**Anahtar Kelimeler:** Taban, temas alanları, maksimal kuvvet, hokey, pedobarografik.

### INTRODUCTION

Ice hockey is one of the most popular winter sports in many developed countries (4,6). Especially in countries such as Canada, the USA and Finland; it is a very important sport. In Canada, there were 550.000 ice hockey players and in the USA there were more than 18.000 ice hockey teams registered to the ice-hockey federation and there were more than 340.000 licensed young players playing in these teams

(18,12,28). In Finland, 45.000 of the 60.000 players were young players aged below 19 years (19). The performance and the success of the ice hockey players depend on many factors. The most important of all is the ability to skate (4,9,10) and many experts were in agreement with the fact that the most important ability in ice hockey is to skate with a roller skate, the reason of which is that skating with a roller skate requires high coordination (5). Speed and ability of the hockey players depend on the skate blade under the skate and

on the ice (8). Particularly; the blades under the skate has a structure that makes it difficult to balance. Skating and gliding on these blades with two feet is the most important ability of the hockey players (5). Ice hockey is a kind of sports with speeding, sharp turnings and sudden stops (21). The game is consisted of these movements (left cross-over turn 20.2%, gliding left-turn 17.8%, right cross-over turn 17.7%, gliding right-turn 16.4%, stop and start 10.4% ) (5). Therefore, it is highly important that the effect of the ice hockey on feet and ankles in the skates should be of optimal degree and there should be a balance between the drive powers (21).

Function of the sole became particularly significant in sportive events (1). Sole was designed for force, flexibility and coordinated movements. The main role of those body parts is providing transmission of force in order the motor activities including walking, running and jumping to be created (30). Significant portion force in the body is produced by the pressure applied by the foot on ground (23,27). It continues through all organs including muscles, joints and bones (23).

Primary sole disorder is metatarsalgia (14). Metatarsalgia is a problem which arises after repeated pressing against of the metatarsus heads and which is observed widely in the society. The load carried by metatarsus heads during walking differs from one person to another (7,15). It is known that the imbalances between load distribution and load increase in metatarsus heads are one of the primary reasons for metatarsalgia (14). Various foot problems including metatarsi stress breaking, neuroma, metatarsalgia sesamoid pathology are the results of repeated pressing against of sport (17). The stress breaking of metatarsi is micro breaking caused by the loads commonly coming on bones of sportsmen exceeding physiological limits. The stress breaking of foot occurs more frequently in runners, sports branches that require jumping and dancers (15).

Upon new methods developed in recent years in sole pressure measurement getting more common it became possible to measure load per metatarsus quantitatively. Despite the speed in the development of those methods, knowledge on pressure distribution forms in metatarsus heads are still debated (14,22,13).

Foot pressure measurements became significant for preventing, treatment and rehabilitation of the deformities that could occur in the foot and providing suitable shoe (20). The technological innovations have a positive effect upon the performances of the skating equipments. Yet, this issue has not been dealt properly by the scientific studies (16,25,26).

It is seen that the studies in the literature focus on the safety equipments of the ice hockey players and on their roller skaters. Most of patents of ice hockey are related to blades. The studies on skates are particularly composed of the ones that investigate how to increase the speed movements and how to make easy turn and stop movements. However; our literature search demonstrate that there are almost no study that investigate the effects of ice hockey on ankles and deformities and the available studies focus mainly on ankle. The aim of the present study was to study contact areas of metatarsus head and maximal powers on the contact areas and to explore the effect of the hockey on foot-sole. Also, another aim of the research was to contribute to the researches that design of the skate footbed by determining contact areas of the foot-sole and by exploring maximal power points on these areas in order to produce performance-increasing roller-skates. Through the studies on these issues, load on foot-sole and metatarsus heads is found and thus the production and development of the suitable skate footbed is achieved.

## METARIALS & METHODS

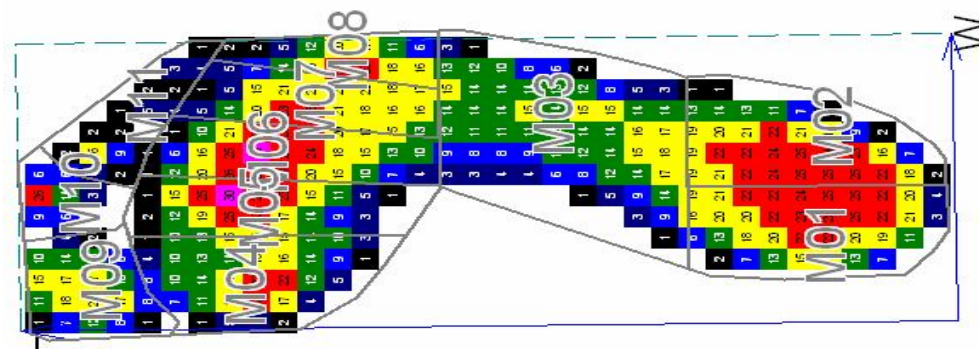
### Subjects

The study included 22 male ice hockey players of Turkish University National Team who had no previous foot injury and complaints (aged  $18,37 \pm 2,2$  years) and a control group of 25 male volunteers (aged  $26,10 \pm 2,40$  years). The average age at which the athletes started playing ice hockey was 9 years. Those with a foot disorder, a neurological disease affecting the movement system, a peripheral neuropathy, players with previous foot or ankle surgery and fracture in this area were excluded from the present study. Age, height, weight and BMI values of all the subjects were measured (table 1).

**Table 1.** Physical Characteristics of Ice Hockey Players (1) and Control Group (2)

Variables	Groups	Mean	SD	X1 - X2	Min	Max	t	P
Age (year)	1	18,37	2,247		16,00	22,00	2,000	,000**
	2	26,10	2,403	-7,73	22,00	29,00		
Height (cm)	1	176,62	3,862		172,00	182,00	74,000	,009**
	2	182,33	8,547	-5,71	164,00	192,00		
Weight (kg)	1	81,00	14,452		63,50	99,00	112,000	,193
	2	88,00	14,05	-8,00	64,00	110,00		
BMI (kg/m <sup>2</sup> )	1	25,94	4,762		20,66	32,45	144,000	,806
	2	26,59	3,375	-065	19,11	30,86		

\*\* P < 0.01 \* P < 0.05



**Figure 1.** Mask areas in pedobarography (M01: medial of heel, M02: lateral of heel, M03: midfoot, M04: 1st metatarsal head, M05: 2nd metatarsal head, M06: 3rd metatarsal head, M07: 4th metatarsal head, M08: 5th metatarsal head, M09: pollex M10: 2nd finger, M11: 3rd 4th and fifth fingers).

### Instruments

Pedobarographic (sole pressure measurements) measurements of the study participants were performed using an EMED-SF (Novel GmbH, Munich, Germany) plantar pressure analysis system at the Gazi University Faculty of Medicine Department of Orthopedy and Traumatology walking laboratory. The system uses a 71 Hz sampling frequency; its dimensions are  $44.4 \times 22.5$  cm; it includes two receptors per  $\text{cm}^2$ ; and it is mounted on a wooden platform of  $7 \times 1$  m and covered by a thin layer of leather.

### Experimental Procedures

The present study was approved by the Local Ethics Committee of the Faculty of Medicine, T.R. Gazi University (February 25, 2008; approval number 074 for non-pharmacological clinical studies). The respondents walked freely on a 7-meter walking band before stepping on the pedobarograph and the area where the measurement was performed is not stated. The measurements were performed with naked feet and two dynamic measurements were performed for each foot. The sole was divided into 11 areas, each of which was evaluated in terms of contact areas ( $\text{cm}^2$ ) and maximal forces (N) (figure 1).

### Statistical Analyses

The data obtained was analyzed using SPSS software (Version 16). The two measurements of the experimental and control groups were averaged and the non-parametrical Mann Whitney-U test was used to test whether there was a statistically significant

difference between the related averages. The extent of the linear relationship between physical structure and the variables for each sole measurement was examined by calculating the Pearson coefficient ( $r$ ). A 95% reliability interval was used and the level of significance was accepted to be  $P < 0.01 - 0.05$ .

### RESULTS

Age, height, weight and mean BMI values were analyzed and there were significant differences between male ice hockey players and control group in terms of age and height ( $P < 0.01$ ).

When the comparison of the right and left feet totals and 11 contact areas of the male ice hockey players and the control group were compared; it was noted that all of the results were significant in terms of lateral of the right heel, 4<sup>th</sup> metatarsal head and means of the 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> fingers ( $P < 0.01-0.05$ ; table 2).

No significant difference existed in all of the results relating right foot in terms of comparison of right and left foot totals and 11 contact areas. As for the left foot; the difference between the means of maximal power TOTAL, 2<sup>nd</sup> metatarsus head (MO5) and pollex was significant ( $P < 0.01-0.05$ ; table 3).

For the categorical comparisons; the size of the linear correlation between continuously measured variables were calculated using Pearson's coefficient. The comparison of contact areas of the right and left foot-sole and maximal power and body weight and BMI gave significant and positive correlations at 0.01 and 0.05.

**Table 2.** Comparison of Right and Left Feet Contact Areas of Ice Hockey Players (1) and Control Group(2)(cm<sup>2</sup>)

Variables	Group	Right Foot				Left Foot			
		Mean	S.D	Mann-Whitney U	P	Mean	S.D	Mann-Whitney U	P
Foot- TOTAL	1	159,71	20,15	131,500	,497	158,36	19,98	129,000	,639
	2	164,35	16,85			160,35	16,73		
MO1: The medial part of heel	1	20,50	1,923	112,000	,181	20,76	2,258	127,500	,601
	2	21,10	2,204			21,10	1,895		
MO 2: The lateral part of heel	1	19,44	1,719	90,500	,041*	20,13	1,903	97,000	,113
	2	20,92	2,369			21,17	2,312		
MO 3: midfoot	1	32,96	7,946	141,500	,728	32,50	9,763	134,500	,781
	2	32,25	8,346			32,17	8,352		
MO 4: The 1st metatarsal head of foot	1	15,37	2,777	136,000	,595	14,40	2,564	97,000	,113
	2	15,77	2,478			15,65	1,828		
MO 5: The 2nd metatarsal head of foot	1	12,15	2,488	111,000	,172	11,13	2,247	90,000	,067
	2	12,95	1,700			12,17	1,914		
MO 6 The 3rd metatarsal head of foot	1	13,25	1,834	105,500	,120	13,20	1,770	119,500	,423
	2	14,12	1,467			13,67	1,515		
MO 7: The 4th metatarsal head of foot	1	11,12	1,936	122,000		10,13	1,159	91,000	,049 *
	2	11,70	,879		,317	11,35	,727		
MO 8: The 5th metatarsal head of foot	1	7,68	1,276	110,000	,156	7,86	1,368	137,500	,861
	2	8,12	,723			7,87	,958		
MO 9: pollex	1	12,71	2,049	111,000		12,73	2,060		
	2	13,57	2,838		,173	13,45	2,181	104,500	,185
MO 10: 2nd finger of foot	1	4,68	,946	139,500	,675	4,30	1,114	142,000	,986
	2	4,75	1,261			4,32	,949		
MO 11: 3.4.5. fingers of foot	1	9,40	2,563	140,000	,690	10,50	2,570	77,500	,024*
	2	9,05	4,189			7,37	3,516		

\*\* P &lt; 0.01 \* P &lt; 0.05

## DISCUSSION

In our study; various contact areas of the foot-soles of the participant male ice hockey players and their maximal force values were analyzed and were compared to the control group composed of healthy individuals. The difference between the participant hockey players and healthy individuals who did not play sports was found to statistically be significant in terms of age and height. That the differences between the groups were not statistically significant in term of contact areas of the foot-soles and the body-weight and BMI which had an effect upon maximal power indicated that groups were homogenous in points of variables investigated (table 1).

In the study, the analysis of the contact areas of the right foot and left foot of the ice hockey players and control group indicated that the difference between mean lateral of right heel and mean left foot fourth metatarsus head was statistically significant in all results (table2). Ripani et al. explained that when the rugby players compared to healthy individuals, both foot pressure area were significantly higher on baropodometric analysis of 23 professional rugby players, and 17 healthy people (24). There are similar studies in different sport branch. Aydos informed that

the control group's right heel medial, left heel lateral, right foot 3, 4 and 5 metatars head is higher than the wrestlers' the difference between means in the Comparison of 11 contact area in the study conducted to the elite wrestlers (3). In the study of basketball players, it was indicated that professional basketball players, the right foot 2 and 3 metatars heads, the middle part of the left foot, 2 and 3 metatarsal head are less than sedentary healthy people who don't do sports and contact area of 2 left finger is greater than in the control group in terms of differences between means (29). Aydos et al. (2) indicated that in the study of the effects of volleyball's contact to area soles of the feet, volleyball players' foot contact soles values are lower, but there is no statistically significant difference in the comparison of volleyball players' and healthy women's, who don't do sports, right and left foot contact soles. In this study, although the contact areas of the foot-sole on the 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> fingers of both feet were bigger among the male ice hockey players; all of the other concerning results were smaller than the control group. In light of these results; it may be said that using skates does not help players get power on their fingers but step on the ground. It may be suggested that the fact that other contact areas were poor caused more power from the

ground and certain power sites focused on the foot-sole. Considering that power production starts from the foot-sole; the player needs smaller pressure sites but bigger pressure while speeding and accelerating. While doing so, contact areas that produce power

should become smaller. It was due to the fact that ice hockey players used lateral of the right foot heel actively when stopping and speeding that the difference in the lateral of the right foot was significant and smaller.

**Table 3.** Comparison of Right and Left Feet Maximal Forces of Ice Hockey Players (1) and Control Group (2)

Variables	Group	Right Foot				Left Foot			
		Mean	SD	Mann-Whitney U	P	Mean	SD	Mann-Whitney U	P
foot- TOTAL	1	1083,18	187,15	118,000	,260	1052,93	199,30	90,000	,049 *
	2	1150,83	179,6			1170,0	176,2		
MO1: The medial part of heel	1	373,23	100,63	104,500	,116	388,20	69,18	115,500	,349
	2	428,90	97,55			431,86	120,2		
MO 2: The lateral part of heel	1	328,26	92,18	136,500	,608	329,93	65,29	142,000	,986
	2	336,77	77,50			328,80	71,72		
MO 3: midfoot	1	220,65	113,21	125,500	,380	224,90	150,91	130,500	,677
	2	180,67	68,59			185,48	75,06		
MO 4: The 1st metatarsal head of foot	1	200,84	84,51	143,000	,766	161,18	70,98	100,000	,140
	2	213,23	84,63			194,73	69,48		
MO 5: The 2nd metatarsal head of foot	1	233,18	61,09	117,000	,246	210,03	61,43	91,000	,044*
	2	259,96	54,69			252,66	64,21		
MO 6 The 3rd metatarsal head of foot	1	243,25	51,37	139,500	,679	246,28	57,35	116,000	,358
	2	251,36	57,72			270,46	64,14		
MO 7: The 4th metatarsal head of foot	1	159,59	50,43			174,41	61,81		
	2	157,65	40,41	147,000	,868	166,91	47,33	133,000	,742
MO 8: The 5th metatarsal head of foot	1	77,26	22,91	120,500	,297	107,25	63,88	133,000	,742
	2	84,90	27,96			105,07	48,30		
MO 9: pollex	1	182,51	67,28	150,000		142,06	64,89		
	2	185,81	91,35		,947	197,21	85,40	85,500	,048*
MO 10: 2nd finger of foot	1	33,62	16,11	126,500	,398	24,75	11,53	112,500	,298
	2	39,01	21,93			29,50	13,05		
MO 11: 3.4.5. fingers of foot	1	40,29	26,65	126,500	,398	43,55	26,22	105,000	,193
	2	49,40	36,48			28,20	22,55		

\*\* P < 0.01; \* P < 0.05

**Table 4.** Correlation between Physical Structure and Foot-Sole Variables of Ice Hockey Players (1) and Control Group (2)

Variables		Age		Height		Body Weight		BMI	
		1	2	1	2	1	2	1	
Right Feet Contact Areas Total	r	,411	-,208	,046	,603**	,871**	,374	,837**	-,028
	p	,114	,379	,865	,005	,000	,105	,000	,906
Left Feet Contact Areas Total	r	,099	-,204	-,091	,626**	,634*	,393	,624*	-,022
	p	,726	,389	,748	,003	,011	,086	,013	,928
Right Feet Maximal Forces Total	r	,089	,468*	,099	,476*	,930**	,920**	,898**	,747**
	p	,744	,037	,715	,034	,000	,000	,000	,000
Left Feet Maximal Forces Total	r	,124	,393	,037	,413	,666**	,931**	,627*	,814**
	p	,660	,086	,896	,070	,007	,000	,012	,000

\*\* P < 0.01 \* P < 0.05

In the normal step analyses; it is reported that more pressure occurs on the medial region rather than lateral region (11). That the fourth metatarsus head of the left foot was statistically significant may be resulting from the outward movements of the players when speeding in order to get a sufficient acceleration. Also, that the foot-sole is hard creates difficulties for the foot-sole in terms of the movements during the trainings and competitions; which may be called adaptation of the body because contact areas become smaller in order to shorten reaction time. As a result; that was why contact areas were smaller among the ice hockey players compared to the control group.

According to the comparison of the TOTAL of the right and left foot and 11 contact areas of the ice hockey players and the control group in terms of maximal power; there was no difference in right foot in all results whereas there was a statistically significant difference in the left foot in terms of TOTAL maximal forces, mean 2<sup>nd</sup> metatarsus head (MO5) and mean pollex (table3). It was stated that there were significant differences on the right and left foot 2. metatarsal heads and was found similar results in other regions in the women volleyball players' comparison of maximal force contact area soles of the feet between averages (2). In this study which has been investigated maximum force applied at the ground contact of the foot, it was stated that for basketball players, while the right 1 Metatarsal head, the big toe and left foot 2. Metatarsal head was lower than people who don't do sports, right foot 4. metatarsal head and left foot 2. finger was bigger (29). When the control group and wrestlers were looked into, wrestlers' right foot heel medial, 2. metatarsal head and right foot, totally left foot 2. metatarsal head, left foot 5 metatarsal head and the left foot, totally is more than wrestlers' have been identified (3). In our study, it was found out that all maximal power values were smaller than maximal power values of the contact areas of the control group. It is a reality that players need power more than normal people during the sportive activities. In the normal step analyses, maximal power values of the ice hockey players were smaller than the control group; which indicated that players had the capacity to use their feet more economically and productively -than people not doing sports- non-sports-doing. Particularly, that the difference occurs on the left feet values shows that ice hockey players have left foot as balance tool and use it more actively in shots and accelerations.

According to the results of other studies; there was a linear and positive correlation between age, body height, body weight, BMI and the contact areas of the right-left feet and maximal powers.

The effects of the effect of making shoes and the distribution of the effects of the regional forces in the soles of feet to making shoes were investigated in a

study of 22 people by using 19 different models of shoes in differential pressure sensors. All shoes are composed of high-quality running shoes. Data at natural walks made from the 3.3 m / sec with reaction force and pressure distribution by being determined mechanical properties by shoe pressure gauge tool were collected. 22 shots, model-by-step lateral edges of the rise in the pressure was too medial foot. In this study, analysis of the distribution of the pressure in shoes, shoe-making, and the numerical relationship between feet complaints have been identified (11). This study was in agreement with our study. The reason why pedobarographical parameters of the ice hockey players were lower might be due to their age, BMI, strong lower extremities and strong balance ability.

According to the results of the study that investigated ice hockey players and normal people who did not do sports; age, body height, body weight, BMI, the contact areas of the right-left feet and the contact areas were compared. So, there were significant differences between the sports done by the ice hockey players and measurements of foot-sole variables in terms of 11 contact areas, lateral of the right feet and 4<sup>th</sup> metatarsus head of the left foot. As for the maximal power of the contact areas; a significant difference occurred in the left feet total, 2<sup>nd</sup> metatarsus head and pollex.

As a result; it was understood that ice hockey caused certain changes in some areas of the foot-sole but no damage was seen in the foot-sole in the general sense. Particularly, it was seen that shoes used by the players were partly successful in supporting and protecting foot-sole. Also, it may be concluded that taking the changes in metatarsus heads indicated by the study results into consideration will contribute to the protection of the foot-structure of the ice hockey players and increase their performance. In light of these conclusions; it may be suggested that ice hockey did not create such a serious change to require a medical intervention on the foot-soles of the players

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