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STUDENTERRAPPORT

EFFECT OF SLIP PATCHES ON FOOTCONTACT MECHANICS DURING A HANDBALL MOVEMENT

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Abstract

Objective: *to investigate the effects of Spraino patches on foot-surface interaction during a handball specific cutting task.*

Method: *Nine female elite handball players participated in the study where four patch conditions were tested when applied the outsole of a commercially available handball shoe (Adidas Stabil Boost) during a sidecut movement while receiving a pass. Kinematic data were recorded with a motion capture system.*

Result: *The patches did not affect contact times or maximum vertical GRF of the cutting foot. There was no significant effect on the GRF, ankle kinematics or ankle moments during EC and LC. The overall GRF was not affected and movement technique was not altered.*

Discussion: *No final conclusion may be offered at this stage while the intervention provides some interesting results with regard to ankle loading during handball. It needs to be investigated how different player actions are affected by such interventions. Such future testing needs to include performance relevant measures to attest the applicability to handball training and games.*

Introduction

Ankle injuries and primarily ankle sprain is the most common among lower limb injuries. Dallinga et. al. (2016) reported that high number of ankle injuries occurs in the most common team sports like football, handball, basketball and volleyball *(6)*. Approximately 80 % of ankle injuries are ligamentous sprains and the remaining 20% are ligament ruptures *(4)*. A Junge et. al. (2006) analysed the different injuries in 8 team sports during the 2004 Olympic Games in Athens. They recorded 48 ankle injuries *(11)*. This type of injury aside of the mechanical and structural alterations can induce changes in the function of the neuromuscular system and influence the motion. Studies reported that depending on the requisition of each team sport, from 9 to 40% of the team players suffering of instability, increased risk of injury and degeneration for a long term after ankle sprain *(3, 4, 6, 16)* The mechanical aspect of the lateral ankle sprain is, when the vertical axis of the centre of the body mass placed outside of the vertical axis of the ankle joint, excessive inversion happen on the ankle which often paired with forced plantar flexion *(9)*. The ligament structure of the ankle composed by three major ligaments which ensure the lateral stability of the ankle. These three ligaments, commonly called the lateral complex, are the anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL) and posterior talofibular ligament (PTFL). Lindner et. al. (2011) and Maffulli et. al. (2012) suggested the ATFL is more prone to injure among the ligaments of the lateral complex because ⅔ of the total number of ankle injuries are ATFL wounds. *(13, 14)* Kristianslund et. al. (2011) published a study about an accidental ankle sprain during a sidestep laboratory test after two successful trial. After the data comparison they described the kinematics and kinetics during the injury *(12)*. The investigation of Chu et. al. (2010) found the same kinematic and kinetic results about this topic *(4)*.

Research groups tried to find a method or develop a device to prevent ankle injuries. Taping, bracing, neuromuscular training and orthosis were involved in these studies, and compared in order to derive the most effective way of their application which was the combination of the different devices and methods *(7, 10, 17, 18)*. Curtis et. al. and Nembhard et. al. (both 2008) investigated the difference between altered shoe designs but none of these studies were found significant difference between designs *(5, 15)*, and there were investigations with wearable electric and regular devices which were different to the affore mentioned subjects, but fundamentally more close to the solution which is in focus in the present study. To the knowledge of the authors there are no studies about the effectiveness of these devices so far *(2, 8, 19)*.

The purpose of this study was to test a new Danish invention to prevent ankle sprain called Spraino. Spraino is an adhesive plaster coated with a thin teflon layer which fixed to the lateral side of the shoe including a thin line on the ground-engaging surface ensuring the sliding effect when the ankle inversion become too high. The investigation focused on the ideal position of the adhesive plaster on the shoe side and outsole and the effect on movements during the test subjects executed sidecut movements. The female handball players subject group was chosen, because as Dallinga et. al. (2016) shown in the indoor and court sports more ankle sprain occurred among female players than men regarding to other studies *(6)*. Handball was chosen because as Junge et. al. (2006) shown in the 2004. Olympic Games, the total number of ankle injuries among the 8 team sports were 49, and only in handball were 12 which means ~25% of the injuries occurred in handball which was the highest proportion among team sports *(11)*.

Method

Subject information

9 female subjects (age 21±2,4 years, height 176,6±9,84 cm, weight 73,8±9,7 kg) participated in this study *(table 1)*. The subjects were not affected by any musculoskeletal illnesses or chronic pain conditions. Prior to the test, each subject signed an informed consent statement.

Subject	Leg dominancy	Height (cm)	Weight (kg)	Age (year)
1	R	160	55	26
2	R	167	52	26
3	R	182	81,1	21
4	R	184	75,9	18
5	L	164	77,2	18
6	R	192	87	20
7	R	180	82	20
8	R	176	67	22
9	R	178	72	22
	Mean	176,6±9.84	73.8±9.7	21±2.4

Table 1: data of the subjects

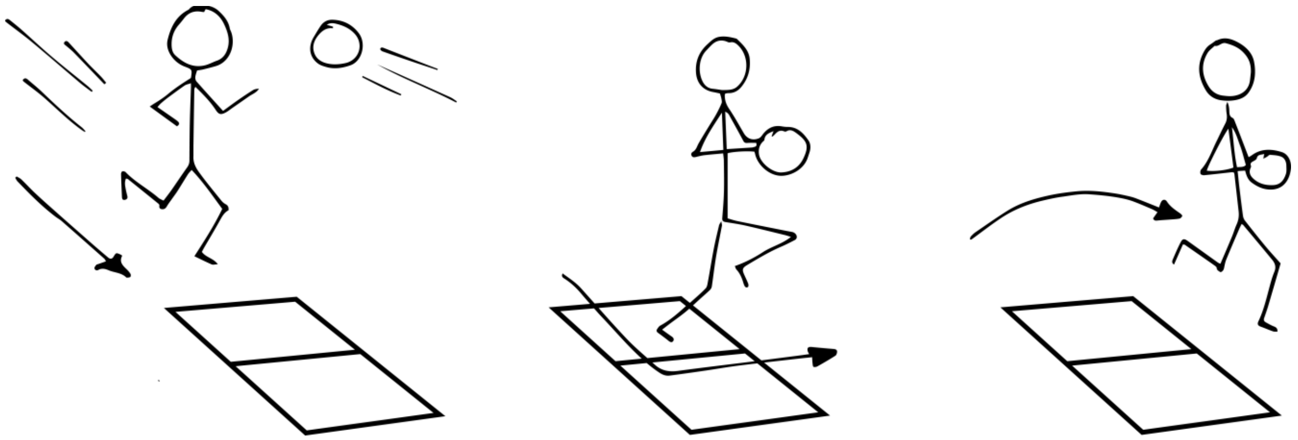

Figure 5: sketch of the execution of the sidecut movement

Protocol

The subject was introduced to the study protocol and lab facilities in order to acclimatise to the new environment. The subject was ask to initiate the acceleration from a self-chosen point in order to obtain sub-maximal speed in the sidecut movement. The subjects received a pass to simulate regular handball strike conditions. When the subjects reached the force plates, they took a step on them and executed a sudden sidecut which was instructed to land in ± 22,5° landing zone in respect to the longitudinal axis of the force plates. If the final position of the subject was out of the zone the trial was discharged and repeated *(figure 5)*. Every subject had to accomplish five successful trials for each intervention. The subjects were using their self-chosen leg to execute the movement.

Experimental method

Every trial was recorded by Qualisys Track Manager System v. 2.9 (Qualisys, Sweden). The system is made up by eight Oqus 1 infrared high-speed cameras which recorded the trials at a 100 Hz sampling rate. The camera system was combined with force plates, to measure ground reaction forces, two AMTI (MA, USA) force plates version OR-6-5-2000 and OR6-7-1000, with a sampling rate of 2000 Hz filtering at 1000 Hz. 35 reflective markers were placed on each subject's body in accordance to a full body protocol in order to track the motion of each subject. In addition, the markers were placed on anatomical landmarks to ensure the least amount of movement relative to the underlying bone. The subjects wore tight fitted shorts and tight sport bras, which covered the least possible area of the body and enabled the markers to be placed directly on the skin of the subjects. The subjects wore the same type Adidas Stabil Boost 1.0 shoes each equipped with 5 retro-reflective markers. The subjects ran through a time-gate system, which was enable to measure the velocity during each trial, just before receiving the pass. The authors made a shoe size survey, prior testing, between the players of the team and used 12 pairs of shoes between 38-40 European sizes, four pairs of each size. These embrace the sizes which best fit to the players of the team. During the study two versions of Spraino were used *(figure 3).*

The difference between the original and the new version was the shape of the edge of the patch which fixed to the outsole. The original version was straight while the new version has a sinusoidal shaped edge and the surface of the shoe outsole larger, therefore it provides a slightly increased friction coefficient which supposed to be slows down the sliding velocity.

The Spraino placed differently to each shoe which is indicated by figures. As figure 4 shown on shoe number 1 the patch covered an area 1 cm of the edge of the outsole over the lateral edge of the sole, on shoe number 2 it was 3 mm which was the recommended distance by the producer. On shoe 3 was the new sinusoidal shaped Spraino with the recommended distance as well and shoe number 4 was a control specimen without Spraino on the sole but only on the lateral side of the shoe. The shoe number 4 was equipped in a way that it functioned as control and blindness in the study.

Figure 3: original (left) and sinusoidal (right) version of Spraino

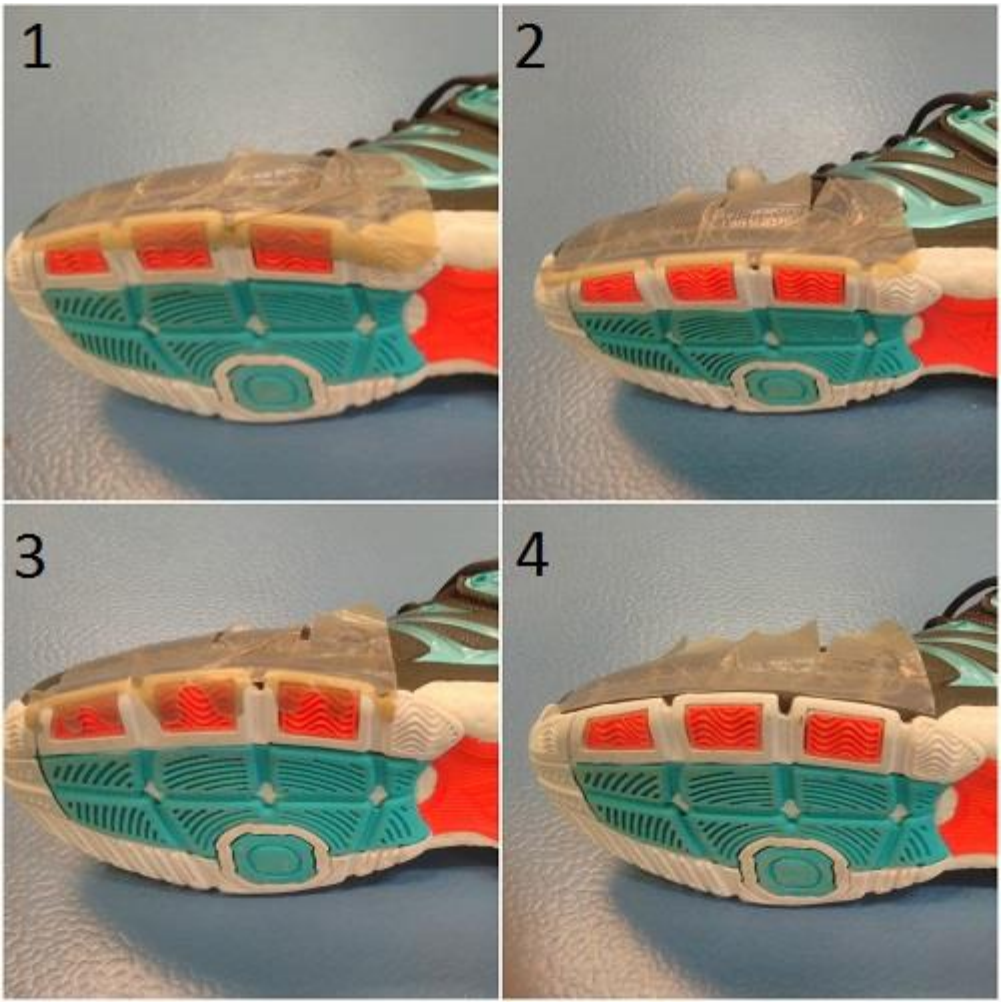

Figure 4: difference between the placement of Spraino on shoe 1, 2, 3 and 4

Computational method

The skeletal models used in this study, were created using the Visual 3D v 5 Professional modelling system (C-Motion Inc., USA). The Qualisys C3D files were applied to the body segments template of C-Motion for scaling the model to the size of the different subjects. The data obtained by Qualisys was driven each skeletal model. In order to minimize the fluctuations of the data trajectories a 4th order, zero phases lag, low pass Butterworth filter was applied with 14 Hz cut-off frequency, respectively. The inverse dynamics were used in order to extract biomechanical parameters about kinetics and kinematics around ankle joint. The ground reaction forces(GRF) were also extracted from the files. The analysed movement was divided to the whole forceplate contact phase as well as first and last 30 ms, designated as early contact (EC) and late contact (LC), respectively.

The authors initially presumed that the control patch has the highest mean of vertical GRF and it's gradually decrease over the larger covered area of the outsole. If a sliding affect were different from control condition it would express by a longer contact time (Tcontact) and greater range of motion (ROM). Also, it was the presumption of the authors that the sinusoid shape patch would increase the friction coefficient and enables gradual gripping ability.

	MaxFx	MaxFy	MaxFz	MinFx
1cm	1,1231 (±1.45) N/kg	0,3060 (±0.34) N/kg	30,2149 (±9.79) N/kg	-7,5340 (±4.27) N/kg
3mm	1,5057 (±1.94) N/kg	0,2864 (±0.36) N/kg	29,5014 (±7.98) N/kg	-14,2934 (±29.38) N/kg
Sinusoidal	1,2405 (±1.76) N/kg	0,3182 (±0.31) N/kg	32,1595 (±8.35) N/kg	-12,9487 (±21.57) N/kg
Control	1,0708 (±1.71) N/kg	0,3703 (±0.45) N/kg	28,0901 (±9.18) N/kg	-11,8026 (±18.92) N/kg

	MinFy	MinFz	TDAnkleAngle	TOAnkleAngle
1cm	-3,1208 (±2.06) N/kg	-2,7646 (±1.60) N/kg	13,7389 (±6.49)°	22,7046 (±8.74)°
3mm	-6,8021 (±19.62) N/kg	-4,4017 (±10.66) N/kg	14,5324 (±6.83)°	23,4807 (±9.24)°
Sinusoidal	-5,0030 (±5.32) N/kg	-2,7724 (±2.41) N/kg	16,8267 (±5.97)°	22,4252 (±9.54)°
Control	-4,1046 (±7.16) N/kg	-2,5334 (±2.04) N/kg	15,8040 (±6.58)°	22,5496 (±7.88)°

	MaxAnkleAnglex	MaxAnkleAngley	MinAnkleAnglex	MinAnkleAngley
1cm	-216,7371 (±8.97)°	27,3390 (±7.56)°	2,4249 (±6.21)°	-53,7708 (±197.45)°
3mm	-167,3709 (±8.48)°	31,1742 (±7.55)°	0,5945 (±5.71)°	-51,9262 (±197.03)°
Sinusoidal	-303,2937 (±6.54)°	30,6939 (±8.51)°	3,4443 (±6.28)°	-69,1302 (±242.45)°
Control	-169,4366 (±7.78)°	29,0874 (±6.67)°	2,6720 (±4.76)°	-66,6072 (±236.74)°

	ECAnkleMx	ECAnkleMy	LCAnkleMx	LCAnkleMy
1cm	0,1513 (±0.31) Nm/kg	-0,1143 (±0.07) Nm/kg	0,3360 (±0.25) Nm/kg	-0,0662 (±0.04) Nm/kg
3mm	0,2364 (±0.38) Nm/kg	-0,0795 (±0.15) Nm/kg	0,3023 (±0.22) Nm/kg	-0,0568 (±0.04) Nm/kg
Sinusoidal	0,2049 (±0.43) Nm/kg	-0,1667 (±0.79) Nm/kg	0,3076 (±0.27) Nm/kg	-0,0965 (±0.04) Nm/kg
Control	0,0907 (±0.36) Nm/kg	0,0716 (±0.87) Nm/kg	0,3343 (±0.29) Nm/kg	-0,0703 (±0.03) Nm/kg

	MaxAnkleMx	MaxAnkleMy	ROMx	ROMy
1cm	1,9796 (±0.66) Nm/kg	0,1678 (±0.24) Nm/kg	15,1536 (±5.89)°	13,6407 (±5.93)°
3mm	1,9955 (±0.77) Nm/kg	0,1530 (±0.18) Nm/kg	17,3902 (±6.44)°	14,0554 (±6.10)°
Sinusoidal	2,0380 (±0.87) Nm/kg	0,4233 (±1.67) Nm/kg	16,9924 (±6.14)°	14,6421 (±4.94)°
Control	1,9470 (±0.70) Nm/kg	0,4917 (±2.03) Nm/kg	15,5310 (±5.68)°	14,8417 (±6.07)°

	ROMz	Tcontact
1cm	17,0936 (±6.17)°	0,2785 (±0.03) s
3mm	16,9136 (±5.16)°	0,3066 (±0.04) s
Sinusoidal	18,6151 (±7.66)°	0,2842 (±0.04) s
Control	17,2863 (±4.98)°	0,2891 (±0.03) s

Significant

Not significant

Table 2: means and standard deviation of the 20 parameters of interest

Statistics

The inverse dynamics analysis gave multiple results of force, moment, and angle values. The contact time was also measured, which is the elapsed time as long as the shoe is in contact with the forceplate. The authors have chosen 20 parameters of interest which could show difference if a sliding effect or a change in movement performance occur during the present investigation *(table 2).* All parameters involving force components, like moments and GRF, were divided by the subjects weight in order to allow subjects comparison. IBM SPSS 24 was used for the statistical analysis. Analysis of variance (ANOVA) was used to investigate if there any significant differences between each of the 20 chosen variables of interest and the between the performance of each patch. If a difference was found a post-hoc Tuckey test was used to find the patches that differed. Statistical significance was set to $P \leq 0.05$.

Results

The results of the repeated measure ANOVA in the present study shows did not revealed significant difference between the control shoe and the three patches under investigation. The results did not revealed significant difference between the three patches under investigation. The descriptive statistics table shows the means and the standard deviation of the 20 parameters of interest for each patch. The SD values revealed large deviation from the mean values in the case of all parameters *(table 2).*

Discussion

In this present study the subjects performed a simulation of a match-like situation, executed a sidecut and received a pass. The attempt was to simulate authentic playing circumstances as close as possible to real play with regard to the velocity, cutting angle and ball distraction situation.

With regards to the results the patches did not affect the contact times significantly. As presumed by the authors if a sliding affect which different from control condition have occured that may be expressed by a longer contact time. This may indicate that the shoes were not sliding. However, the subjects also have stated that they did not experienced sliding effect. Although the difference is not significant, the contact time figure 6 shows that the contact time produced by the patch 1, the patch 3 and the patch 4 is nearly the same while the recommended patch 2 (3mm) tended to increase the contact time in comparison to the other patch fittings. The presumption of the producer of the sinusoid shape patch is to increase the friction coefficient of the shoe when it's occur as the patch

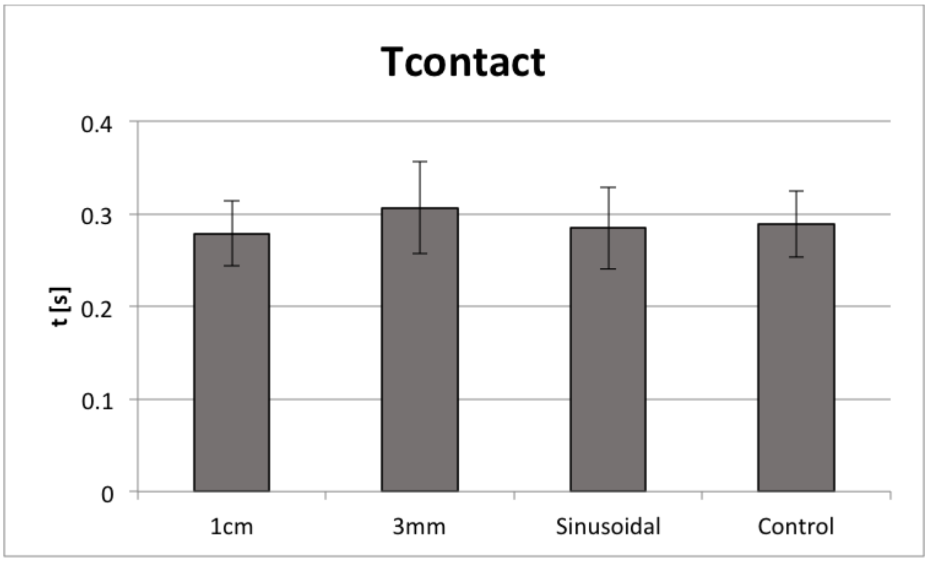

Figure 6: means of the contact time and standard deviation to each patch

keeps some parts of the outsole uncovered and therefore enables a gradual gripping ability to the sole.

As in the case of the contact time, the GRF was not affected by the patches. Regarding to Kristianslund et. al. (2011) where the mean maximum vertical GRF was not larger than 2300 N during a normally executed sidecut and if a sliding effect or injury occured during the movement, the mean maximum vertical GRF was increased to nearly 3000 N. In the present study the results were not larger than the 2300 N the averagely 30 N/kg. This result suggests that the effect of the patches on the shoes are not significant. However, the result was not significant, as figure 7 shows, the control patch has the lowest mean of vertical ground reaction force which result is the opposite of the authors assumed. There was no significant effect of the patches on EC vertical GRF and ankle kinematics and moments, nor LC vertical GRF as well.

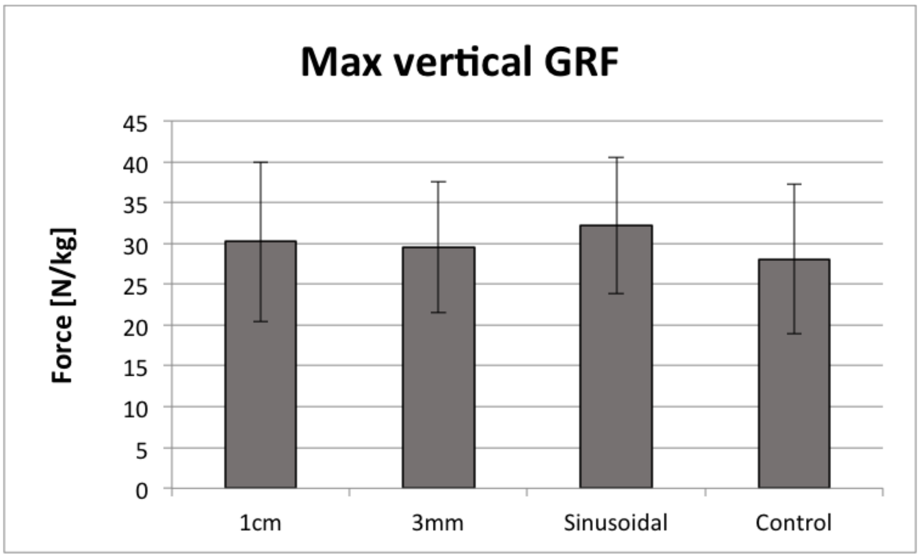

Figure 7: means of the vertical maximum ground reaction force and standard deviation to each patch

The maximum inversion moment did not show significant difference, which may indicate the patches are not affect the inversion moment. On the other hand, in this study the value of this parameter was nearly the double of that which Kristianslund et. al. (2011) measured. During and executed sidecut they did not measured larger moment than 50 Nm and in the present study the moment-weight proportion is ~2 Nm/kg. The results may indicate that the EC and LC phase is not affected by adding these patches as well. *(figure 8).*

The different patches condition did not show any significant effect on the range of motion (ROM) of ankle angle in sagittal, vertical and longitudinal axis. Initially the authors presumed that the plantar-flexion ROM will be larger than 40° in case of a sliding effect in plantar-flexion and also larger than 30° in inversion, referring to Kristianslund et. al. (2011) where during the sidecut movement the plantar flexion range of moment was not lager than 20° and during a sliding effect or injury it was more than 40° and in the case of inversion was not larger than 17° and during sliding effect or injury it was more than 30° *(12),* but because sliding effect wasn't experienced the ROM was under the limit of the normal tresholds and the patches shown the same pattern in the case of the plantar-flexion *(figure 9)* and the inversion parameter as well. This results indicates that the patches on shoes did not increase the inversion, plantar- and dorsal-flexion of the foot, which decrease the probability of a subsequent ankle injury.

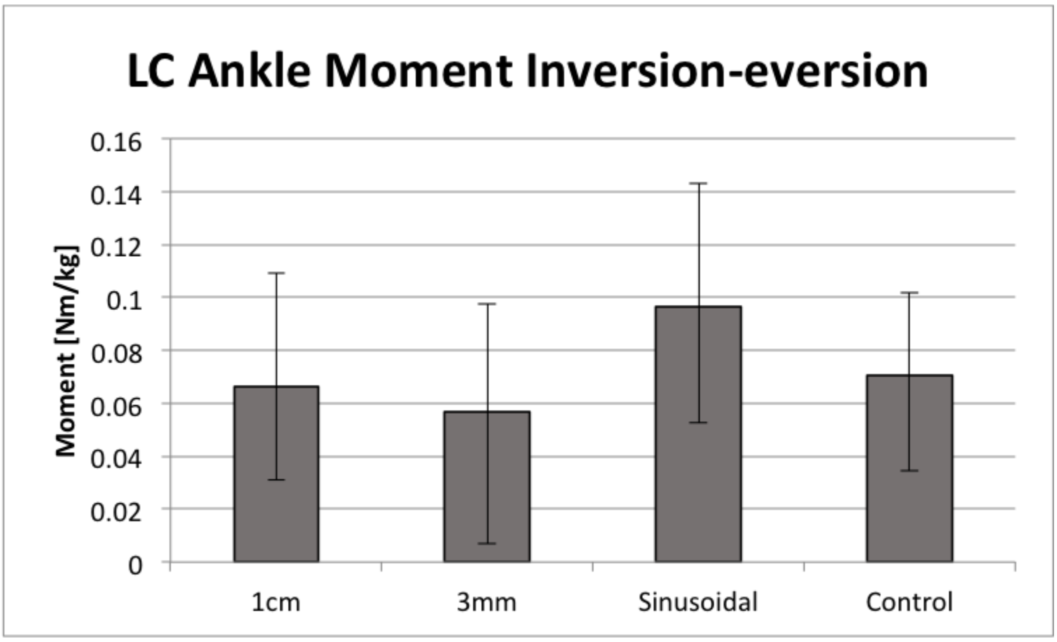

Figure 8: means of the vertical late contact moment and standard deviation to each patch

The main presumption of the study was whether the different patch condition affected the kinematics and kinetic of the ankle joint.
The authors did not observed differences in the ankle movement pattern between the trials with each group of patches.
To the knowledge of the authors no other research group have been investigate similar solution against ankle injuries. So far there is no recordings about an athlete injured while the patch was on its shoe, but there are video recordings about athletes who avoided ankle sprain injuries with Spraino on the shoe. Compared to the previous studies the Spraino has some plausible advantages. Dizon et. al. (2010) stated that using tapes, braces or orthosis can be effective if these were applied with limited range of motion. In contrast with Spraino it is not limiting the ROM as figure 9 shows *(7)*. Verhagen et. al. (2010) and Thacker et. al. (1999) suggested that the combinative application of the most common preventive methods has the best possible result in ankle sprain prevention, but to use these methods are all requires preparation on the human body while Spraino is fixed on the shoe until the replacement of the patch and it is not required to use other devices or methods in concert *(17, 18)*. There were research studies between altered and regular shoe designs but none of these studies found significant difference between shoe designs. These altered designed shoes are more likely to be more expensive than a regular shoe which not comparable the cost of an adhesive patch *(5, 15)*. Attia et. al. (2015) and Fong (2012) developed wearable devices. These devices require battery, bluetooth connection and operates with small electric stimulations which conditions are not

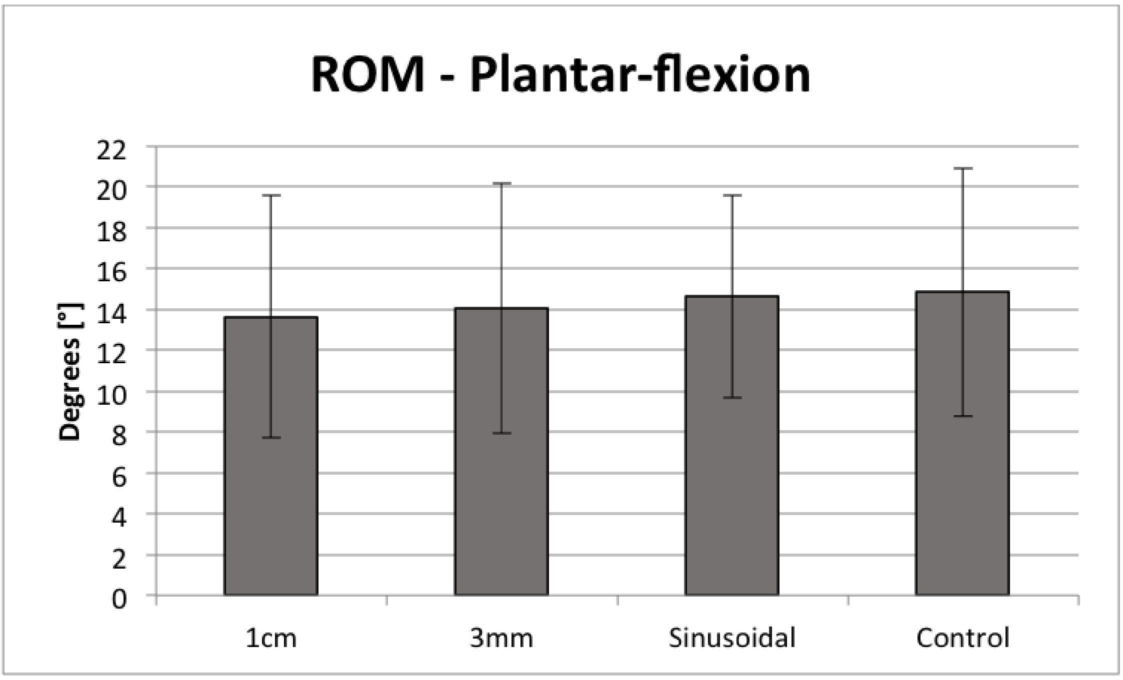

Figure 9: means of the range of motion and standard deviation to each patch

comparable with the simple, light and comfortable patch. The weight of the devices have a significant role in athletes performance.

There are drawbacks of the present study. Initially 16 first class female handball players were take part in the tests, but in the progress of the evaluation process the authors discarded 7 players and only 9 players data were used in the present study. However the number of subjects was enough, higher number of players data could have resulted in more precise results. The recruitment of professional handball players was problematic but the initially aim to test professional players was completed.

During the evaluation of the data the authors faced the problem that high proportion of the subjects had a thick fat tissue around the body. For the reason of this attribute not all of the retro-reflective markers were visible for the cameras and the recorded data was not eligible for further investigation. That was the reason of the authors discarded 7 subjects.

The base of the setup was the investigation of Kristianslund et. al. (2011) which used the same movement and motion capture system like the present study. The Qualisys system in the AAU Gait Lab has to monitor the whole volume of the area of interest by all of the cameras in use and at least three cameras have to see a retro-reflective marker at the same time to obtain reliable data. During the evaluation the authors experienced multiple short moments when a marker was blind, therefore many trials were discarded of this reason. This problem revealed that the test movement or the area of the interest should be change in order of the better visibility of the markers and to get valid data. Also, the authors should find another test movement for the subjects which may show possible difference between the patches, considering there was no difference in the sidecut movement.

The method which was chosen for the analysis and statistics is contributing to the relative large computed standard deviation which is not a problem when there is no significant difference, but it could make a statistical significance unlikely.

Conclusion

The present study displayed the effect to the ankle kinematics and kinetics of the Spraino adhesive patches which covered different size area of a handball shoe outsole. The results suggest that the different positions of the Spraino adhesive patch on the shoe outsole did not affect significantly the movement performance and technique. The difference in subject ground contact times, ankle angles and ROM values as well as the ankle moments and GRF were not significant. The results of the present study indicate that in the applied conditions the Spraino does not show changes in performance and technique regardless of the distance of the edge of the outsole or the shape of the patch, but no final conclusion can be offered at this stage. The results may suggest that the patch 2, recommended by the producer, may ensure the same movement technique and performance features. In parallel, Patch 3 did not show any effect on technique with regards to control patch, but shows significant difference with regards to patch 1 and 2.

With regard to this suggestion, the precision is not needed to attach the patch correctly to the shoe outsole, in range between 3mm to 10mm, which makes the fixing process relatively fast and easy to perform.

The results also may indicate that to have a mechanical effect, more than 1 cm of the edge of the outsole needs to cover. Further studies have to investigate the maximal distance of the edge of the outsole which enables to use the patch without mechanical effect. Although, the results did not show difference in performance or alteration in technique, those are only valid to the sidecut movement. In the future it is required to investigate the effect of the Spraino patch in other player actions of match situations to gain the fully understanding of Spraino effect.

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