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THE ASSOCIATION BETWEEN ECCENTRIC HIP ABDUCTION STRENGTH AND HIP AND KNEE ANGULAR MOVEMENTS IN RECREATIONAL MALE RUNNERS: AN EXPLORATIVE STUDY

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Abstract

Weak hip abductors may be related with increased hip adduction and knee abduction angular movement, which may be risk factors of lower extremity injuries. Since the role of eccentric hip abduction strength (EHAS) on hip adduction angular movement and the knee abduction angular movement (KABD) remains unclear and the purpose of the present study was to explore the association between EHAS and hip- and knee angular movement. In 100 healthy male recreational runners, EHAS was quantified using an isokinetic dynamometer, while hip- and knee angular movement were collected using pressure sensitive treadmill and Codamotion active marker system. By using multiple linear regression models (n=186 legs), no relationships between EHAS and hip- and knee kinematics were found. A possible reason for the lack of relationship between EHAS and hip and knee kinematics may be owing to differences in the running kinematics. Some runners with weak EHAS may compensate the weakness by leaning towards the stance limb and thereby reduces the demand on the hip abductors with the consequence of increased knee abduction moment, which may lead to an increased knee abduction angular excursion. Possible, others mechanism as the quadriceps strength and activity in the hip and thigh muscles may also be able to explain the lack of relationship that may or may not exist. Despite the inconclusive results of the present study, the findings may suggest that weak hip abductor muscles may be a relevant factor to focus on in future studies.

Key Words: running, prevention, rehabilitation, hip strength, patellofemoral

Introduction

It has been proposed that subjects with weak hip abductors may have an increased risk of lower extremity injuries (Boling et al., 2009a;Fredericson et al., 2000;Niemuth et al., 2005). However, contradictory results have been presented on the relationship between hip abductor strength and lower extremity injuries. Rathleff et al. (2014) concluded no association between isometric hip abduction strength and the risk of developing patello-femoral pain in a systematic review when only including prospective studies. Subsequently a contradictory result was reported by Ramskov et al. (2015) who found eccentric hip abduction strength (EHAS) higher than normal to reduce the risk of patello-femoral pain in a prospective design.

From a biomechanical perspective, Powers has described the potential link between abnormal hip mechanics and lower extremity injuries. Eccentrically weak hip abductors have been associated with increased knee adduction moment due to contralateral pelvic drop; thereby increasing the distance between the line of action of the ground reaction force vector and the knee joint center (Powers, 2010). An increased knee adduction moment is restrained by the iliotibial band and the lateral collateral ligament (Pandy and Andriacchi, 2010). Some subjects compensate for this by moving the center of mass (CoM) closer to the stance limb, while moving the CoM excessively towards the stance limb might change the knee to be exposed to an abduction moment caused by hip abductors being resisting the hip abduction moment (Powers, 2010).

Evidence regarding the potential role hip strength has on hip and knee kinematics in runners is conflicting. Cashman (2012) reported a lacking agreement between studies investigating the relationship between hip strength and knee abduction angle and moment in a systematic review and therefore, it was not possible to make definitive conclusions, leading to a need of more research on the topic. So far this relationship has been elaborated during a single leg squat (Baldon et al., 2011;Claiborne et al., 2006) and in a double legged jump landing (Homan et al., 2013) but still this relationship needs to be elaborated on in a large sample using 3D motion analysis and isokinetic strength measurement during a demanding tasks, like running (Cashman, 2012).

The purpose of the present study was to explore the association between EHAS and hip and knee angular movement in a large study of healthy recreational male runners, as suggested by Powers (2010). Additionally, a subgroup analysis comprising runners with both increased hip adduction and knee abduction immediately after foot strike (initial movement direction), served to include runners that may shifting the center of mass excessively over the stance, which may lead to hip adduction- and knee abduction angle (Powers, 2010).

Materials and methods

Study design

A cross-sectional explorative study was designed, as part of a prospective study (RunTech) investigating running related injuries. Ethical approval of the study was granted by the Ethics committee of North Jutland, approval number N-20130074. Written informed consent was obtained from each participant prior to the test according to the declaration of Helsinki. The study was accepted by the Danish Data Protection Agency.

Study population

One hundred male recreational runners were recruited through advertisements at local races, email distribution to local companies and hospitals and at the local university. All subjects who received an e-mail with information about the study were allowed to forward it to relevant persons. Within the six months of recruitment a total of 207 persons had signed up for the study. Only healthy recreational male runners were included. Inclusion criteria were:

(1) male between 18-60 years, (2) running at least 2 times a week, (3) minimum 2 years of running experience, (4) no injuries within the last 3 months, (5) experienced with treadmill running. Subjects were excluded by the following: (1) no e-mail address or access to the Internet, (2) participation in other sports for more than 4 hours/week, (3) necessity for the use of insoles while running, (4) previous stroke, heart disease, or pain in the chest during training, (5) unwillingness to run in a neutral pair of running shoes or (6) unwillingness to use a global position system (GPS) watch or smartphone to monitor training distances.

Strength test (exposure)

EHAS was obtained with an isokinetic dynamometer (Biodex Multi-Joint System 2; Biodex Medical Systems, Inc, Shirley, NY). Subjects were tested at an angular velocity of 30 degrees per second (Nakagawa et al., 2012b) over a range of motion of 20 degrees from neutral hip alignment to 20 degrees abducted hip in frontal plane. The length of the lever arm on the dynamometer was kept constant during all tests. The standard test procedures from Biodex were applied with the EHAS data being sampled at 100 Hz. Isokinetic data were exported to Matlab (Matworks, Natick MA) for further filtering and processing. Isokinetic data from seven subjects were lost from the Biodex database. Of the five repetitions performed on each side, the highest and lowest peak was deleted and the average of the remaining three was divided by the subject's body weight.

Running test (outcome)

Running kinematics were assessed on a pressure sensitive treadmill (Zebris FDM-T, 1.8kW; Medical GmbH, Germany) at 10 km/h for all subjects after six minutes of running and synchronized with the Codamotion active marker system (Charnwood Dynamics Ltd., Leicestershire, UK). Three Codamotion cameras were positioned in a triangle position approximately 2 m away from the center of the treadmill. The sensors for collecting markers positions were positioned in front, rear left and rear right. Active markers were placed on the shoe over the following anatomical landmarks: posterior surface of calcaneus, head of fifth metartarsal, navicularis, cuboideum and on the skin over the following landmarks: anterior superior iliac spine, posterior iliac spine. Four tracking markers were attached on the outside of femur and tibia and both anatomical and cluster markers were secured with tape to ensure minimal movement artifacts. The tracking markers were used to define the calibration markers, medial and lateral femoral epicondyles and malleolus and head of first metatarsal. Calibration marker positions were obtained with a virtual point marker, creating a vector from the tracking markers to the pointed position. Hip joint centers were estimated according to Leardini et al. (1999) and pelvic width were measured with a slide caliper. Kinematic and kinetic data were exported to Matlab (Matworks, Natick MA) for further processing.

Foot strike and toe off were identified from the pressure data of the treadmill. Initial contact was defined as the point in time where the vertical ground reaction force calculated from the pressure plate in the treadmill exceeded 10 N. In cases where the synchronization was not working properly (11 subjects), the foot strike was estimated from first local minimum of either the calcaneus or metatarsal in the global coordinate system and from the stance length in percent, the toe off was estimated. Both kinetics and kinematics were collected with a sampling rate of 100 Hz.

Hip and knee joint angular movement were calculated for the first 30 cycles of the collected data. From the 30 cycles the 5 cycles in the high and low end of the specific variables were deleted leaving 20 step cycles for calculation of the mean for each subject. Joint angles were calculated according to the rules of Euler angles, using the coordinate system of the distal segment relative to the coordinate system of the proximal segment (Grood and Suntay, 1983). Hip and knee joint angular movement were calculated as the differences between the initial contact angle and maximal angle of the initial movement direction during first 50% of stance.

The first 50% was chosen because this portion of stance is decelerating the mass of the body, in which the muscles of EHAS needs to control hip and knee movements (Souza and Powers, 2009b).

Selection of runners displaying both hip adduction and knee abduction angular movement (knee valgus subgroup)

Several movement patterns may be associated with a weak EHAS. One of these is the combination of hip adduction- and knee abduction angle owing to an excessive shift of the center of mass towards the stance limb (Powers, 2010). A priori, this subgroup of runners was defined as follows: Those increasing both their hip adduction- and knee abduction angle in the range between initial foot strike and 50% of stance.

Statistical procedure

Subject characteristics are presented as medians and interquartile range (IQR), as several variables were not normally distributed. A multiple linear regressions of hip- and knee angular movement with EHAS as the explanatory variable were performed. In addition, a subgroup analysis of the knee valgus subgroup was performed to elaborate the relationship between EHAS and hip and knee movement. The ability of EHAS to explain the variability of each hip- and knee angular movement was assessed with an R-squared value derived from the regression model. The results was evaluated for importance based on the estimates, confidence intervals and p-values (Bangdiwala, 2016;Greenland et al., 2016;Stovitz et al., 2016;Wasserstein and Lazar, 2016). The variables were inspected visually for a linear relationship and outliers from a scatterplot of the dependent variable and the explanatory variables. The homoscedasticity and normally distribution was evaluated using a p-p plot.

Due to concerns about right-skewness of data a sensitivity analyses were performed using robust variance estimation and a bootstrap with 1000 replications was performed to confirm the confidence intervals range. Variables were measured on both legs in a single session and each individual was considered as one cluster with two legs. All statistical analyses were performed using Stata Version 12 (StataCorp LP, College Station, TX).

Results

On median the subjects were 38 (IQR:21) years old, 182 (IQR:8) cm tall and weighed 79 (IQR:12) kg. Prior to inclusion, the subjects reported to spend 3 (IQR:1) hours per week running, covered 25 (IQR:14) km per week and 96% reported to run 3 times a week or more. Eccentric hip abduction strength and magnitudes of the hip and knee joint angular movement for all subjects and the knee valgus subgroup are presented in Table 1. In the total sample (n = 186 knees), EHAS was not significantly related with KABD, knee internal rotation, hip internal rotation and hip adduction angular movement (Table 2). Additionally, the subgroup analysis (n = 46 knees) comprising the knee valgus subgroup, revealed that a 1 Nm/BW increase of EHAS would reduce the KABD by 2.8 degrees (p-value:0.002; 95% CI -4.56: -1.12). EHAS explained 35% of the variability in KABD (Figures 1). However, EHAS was unrelated with hip adduction angular movement, hip internal angular rotation movement and knee internal angular rotation movement (Table 2). The results were confirmed by the sensitivity analyses

Discussion

The main findings of the present study did not reveal an association between EHAS and hip or knee joint angular movement during the stance of running. However, EHAS in runners who demonstrated hip adduction angular movement and KABD during the first 50% of stance was EHAS negatively related with KABD.

Comparison to other studies

Previous work has contradictory results, which could be owing to methodological and subject differences. Baggaley et al. (2015) reported, in agreement with the present findings, no associations between isometric hip strength and hip adduction angle, though they investigated healthy recreational female runners. Heinert et al. (2008) reported, however, differences in hip adduction angle and knee abduction angle when comparing runners with the greatest and lowest isometric hip abduction strength. The relationship between EHAS and parameters describing hip and knee kinematics has been investigated in a single leg squat, which has/may have similar stability demands as running. Baldon et al. (2011) reported no association between EHAS and hip and knee kinematics in the male group and Claiborne (2006) reported no overall association between EHAS and knee abduction but a significant association between concentric hip abduction strength and knee abduction was reported. This was similar for the main group in the present study.

Multifactorial nature

In the total sample, no relationship between EHAS and the kinematic variables was found and in the knee valgus subgroup analyses, EHAS was negatively related with KABD. A possible reason for differences between the main analyses and subgroup analyses may be owing to some runners with weak EHAS may compensate the weakness by leaning towards the stance limb and thereby reduces the demand on the hip abductors with the consequence of increased knee abduction moment. The position of the trunk affects the load on the knee, which will result in an adductor or an abductor moment. This may possibly mask the influence of hip strength on lower extremity kinematics, which indicates the importance of monitoring the lateral trunk motion as a potential compensatory movement, while trying to predict the knee angular movement (Cashman, 2012;Souza and Powers, 2009). Besides the hip abduction strength, a weak quadriceps muscle (Boling et al., 2009b), delayed vastus medialis oblique muscle activity (Van Tiggelen et al., 2009) and delayed onset and shorter duration of gluteus medius activation (Barton et al., 2013) could potentially influence the stability of the hip and knee.

Limitations

A drawback of the present study is the potential bias of using the outcome variables for selecting a subgroup of runners with knee valgus from, which will increase the likelihood of a positive association. Therefore, the subgroups analysis should be interpreted as only exploratory and the findings needs confirmation from additional studies, potentially adjusting for lateral trunk lean and other mechanism influencing the association. Another drawback is the lacking precision of skin markers in frontal and transverse plane angular motion. Skin markers typically overestimate the angles and their fluctuations are greater than they are for bone pin markers (Benoit et al., 2006). This could potentially be a confounder of the presented results. However, several studies have been able to discriminate the kinematics between injured subjects and controls from skin markers (Bolgla et al., 2008;Boling et al., 2009a). Therefore, only large differences between subjects might be detectable and therefore large samples would be necessary to detect differences in the frontal plane.

The lack of relationship between EHAS and hip- and knee kinematics could be owing to a relationship which is mediated from unmeasured variables like passive hip internal range of motion (Bittencourt et al., 2012) or because of the multiple regression model applied in the present model, only captures linear relationship between EHAS and hip and knee joint angular movement (Bittencourt et al., 2016).

Perspectives

Despite conservative rehabilitation, the median recovery time of lower extremity injuries is beyond 2 month (Nielsen et al., 2014). Therefore it is relevant to search for mechanisms that may cause over-use and ways to prevent these problems. Our main findings did not support that weak EHAS is associated with and hip or knee joint angular movement during the stance of running, while runners demonstrating hip adduction angular movement and KABD during the first 50% of stance demonstrated that EHAS is negatively related with KABD. The literature continues to be mixed in its support for this hypothesis and further studies are warranted. Such studies should also measure trunk movement since these movements may be used to compensate for weak hip abductor muscles.

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Figure 1: A multiple linear regression line on the association between eccentric hip abduction strength and knee abduction angular movement (KABD). Knee valgus subgroup: running knees displaying an initial hip adduction and knee abduction angular movement during the first 50 percent of stance.

Table 1: Description of strength and kinematics for all subjects and Knee valgus subgroup

Variable	direction of change	All: mean (+/- sd) & (min-max)	Knee valgus subgroup: mean (+/- sd)
Strength			
Eccentric hip abduction strength		0.79 N/BW (+ / - 0.35) & (0.14-2.04)	0.89 N/BW (+/- 0.32)
Eccentric contraction velocity		30.3 deg pr sec (+/-0.82) & (29-32)	30.37 deg pr sec (+/- 0.76)
Kinematics			
Knee abduction	+ abduction	-3.56deg(+/-5.41) & (-17.67 – 10.48)	2.64 deg (+/- 2.25)
Knee internal rotation	+internal	13.1 deg (+/-13.12) & (0.02 - 28.79)	10.9 deg (+/- 5.82)
hip adduction	+ adduction	2.93 deg(+/-5.93) & ('-29.9 - 16.87)	4.96 deg (+/- 4.74)
hip internal rotation	+internal	-1.73deg (+/-5.57) & (-18.17 - 10.54)	-3.48 deg (+/- 5.88)

Table 1: SD: standard deviation; min: lowest value; max: highest value; knee valgus subgroup: runners displaying an initial hip and knee abduction angular movement and hip adduction angular motion during the first 50 percent of stance. Kinematic variables are joint angular motions from initial contact to first peak

Table2: The regression coefficient between eccentric hip abduction strength and kinematic variables

All subjects; N=186 knees	Hipstrength/BW				
	Coef	L CI	U CI	R-squared	**P>|t|**
Knee abduction	1.86	-0.39	4.11	0.18	**0.1**
Knee internal rotation	0.89	-1.25	3.04	0.29	**0.41**
Hip internal rotation	0.69	-1.41	2.79	0.24	**0.52**
Hip adduction	-1.01	-3.22	1.19	0.19	**0.36**
Knee valgus subgroup; N=46 knees					
Knee abduction	-2.84	-4.56	-1.12	0.35	**0.002***
Knee internal rotation	-3.03	-7.88	1.82	0.41	**0.21**
Hip internal rotation	-3.02	-8.14	2.09	0.29	**0.24**
Hip adduction	2.14	-0.05	4.33	0.41	**0.06**

Table 2: A multiple linear regression and a simple linear regression with knee abduction angular movement explained by eccentric hip abduction strength in all population and in the knee valgus subgroup, which comprises runners with increased knee abduction angle during stance of running. **Coef: regression coefficient; l CI: lower confidence interval of regression coefficient; U CI: upper confidence interval of regression coefficient; p>|t|: p-value; *Significant**