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Original Research

Normal values for hip muscle strength and range of motion in elite, sub-elite and amateur male field hockey players

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ABSTRACT

Objectives: To determine normal values for hip strength and range of motion (ROM) of elite, sub-elite and amateur male field hockey players and to examine the effect of age, leg dominance, playing position, playing level and non-time-loss groin pain on hip strength and ROM.
Design: Cross-sectional study.
Setting: Physical testing took place at field hockey clubs.
Participants: Male field hockey players competing in the three highest Dutch field hockey leagues (n = 104).
Main outcome measures: Eccentric adduction, eccentric abduction, adductor squeeze strength, adduction/abduction ratio, internal rotation, external rotation and bent knee fall out (BKFO).
Results: Strength and ROM values (mean ± standard deviation) were: adduction = 2.8 ± 0.4 Nm/kg, abduction = 2.6 ± 0.4 Nm/kg, adduction/abduction ratio = 1.1 ± 0.2, squeeze test = 4.5 ± 0.8 N/kg, internal rotation = 34° ± 11°, external rotation = 47° ± 9°, BKFO = 15 ± 4 cm. Age, leg dominance, playing position, playing level and non-time-loss groin pain had no effect on these profiles.
Conclusions: Normal values were established for hip strength and ROM of male field hockey players and showed to be independent of age, leg dominance, playing position, playing level and non-time-loss groin pain.
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1. Introduction

Over the past ten years the physical demands in the game of field hockey have increased significantly. The characteristic flexed hip/trunk positions, explosive accelerations and decelerations and sudden directional changes are strenuous, especially for the lumbar spine and lower limbs. Therefore injuries to the groin region are a common problem in field hockey, with a reported incidence rate of 10–12% (Delfino Barboza, Nauta, van der Pols, van Mechelen, & Verhagen, 2018; Hollander et al., 2018).

In field hockey, there is a lack of research regarding causal mechanisms and risk factors for injuries to the groin region. However, field based sports that involve the same characteristic quick movement patterns show that deficits in hip adduction strength and adduction to abduction ratios are important risk factors for future groin problems (Whittaker, Small, Maffey, & Emery, 2015).

Most groin problems appear to be of a gradual onset (Haroy et al., 2017). Research in football has shown that by regularly monitoring hip muscle strength, problems to the groin region can be detected in an early stage and allow timely management to prevent deterioration of the problem (Wollin, Thorborg, Welvaert, & Pizzari, 2018). In players that already suffer from time-loss hip or groin problems, treatment response and the progress of rehabilitation can be determined (Malliaras, Hogan, Nawrocki, Crossley, & Schache, 2009; Nevin & Delahunt, 2014; Thorborg, Serner, et al., 2011).

In addition to monitoring hip muscle strength, comparing these strength measures to established normal values can play an important role in identifying players at risk for developing injuries to the groin region (Mosler et al., 2017; Tyler, Nicholas, Campbell, &

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McHugh, 2001). Normal values for hip muscle strength differ between sports. Despite overlapping characteristics, differences in normal values may be due to differing sport specific loading demands (i.e. kicking, erect trunk posture in football compared with drag flicking and running in trunk flexion during hockey). The respective values for adduction (ADD) to abduction (ABD) ratios, for example in football, Australian football and ice hockey, are 1.20 (Mosler et al., 2017), 1.07 (Prendergast, Hopper, Finucane, & Grisbrook, 2016) and 0.95 (Tyler et al., 2001). Normal ratios may thus differ up to 25% between sports. As such, the risk profile for future groin problems may also differ between sports. Tyler et al. found that ice hockey players with an ADD/ABD ratio of less than 0.8 were 17 times more likely to sustain an adductor muscle strain (Tyler et al., 2001). Mosler et al. found the injury risk threshold to be slightly higher in football players. Here the lower limit of the normal range in was 0.9 (Mosler et al., 2017). Such normal values for hip muscle strength (and therefore also the risk profile) are not available for field hockey.

Hip range of motion (ROM) is another feature that is often determined in the screening and management of groin problems. While the role of strength seems to be well established, there is conflicting evidence on the relationship between ROM and injury risk (Whittaker et al., 2015). There are no publications on normal values for range of motion available in field hockey.

The primary aim of this study was to determine the normal profiles for hip muscle strength and ROM in male field hockey players. To assist clinicians in the interpretation of the normal values on clinical practice we had a number of secondary aims. These were to determine the effect that age, leg dominance, playing position, playing level and current presence of groin pain had on these profiles.

2. Materials and methods

2.1. Study design

Our study was cross-sectional. Players from 12 field hockey teams competing in the 3 highest Dutch field hockey leagues, representing respectively elite (Hoofdklasse), sub-elite (Promotieklasse) and amateur (Overgangsklasse) playing levels, were invited to participate in the study. Seven teams accepted the invitation and agreed to participate. Participation involved completing a questionnaire about groin pain and performing physical tests to determine hip strength and ROM. Prior to the study, approval of the Medical Research Ethics Committee Erasmus MC was obtained (MED-2018-1576). All participants provided written informed consent.

2.2. Injury definitions

In our study time-loss groin pain was defined as groin pain resulting in a player being unable to fully participate in training sessions and match play (Fuller et al., 2006). As such non-time-loss groin pain was defined as physical complaints to the groin region, but without time-loss. Players without any pain to the groin region were defined as asymptomatic players.

2.3. Inclusion and exclusion

The inclusion criteria for participation were: male gender, age 18–40 years, $\geq$ 3 hockey training sessions a week plus match play and able to fully participate in hockey training sessions and match play. Players with current groin pain were considered eligible for inclusion, as long as they were still able to fully participate in training sessions and match play (= non-time-loss groin pain). Players were excluded from participation if they suffered from time-loss groin pain or any other time-loss injury. Exceptions were made for players who sustained a time-loss ankle or foot injury within 7 days prior to testing. Secondly, exceptions were made for players who sustained a time-loss upper body injury within 14 days prior to testing. If players with these recent injuries could fully complete the testing procedures, they were included as we considered them to be capable of delivering representative strength and range of motion values.

2.4. Sport specific questionnaire

A digital questionnaire was used to record the following information: age, leg dominance, playing level, playing position and current presence of groin pain (see appendix for questionnaire) (Langhout et al., 2019). The presence of groin pain was asked using the question: "Do you currently have any groin pain?“. When a player reported any groin pain to be present, the affected side and duration of the groin pain were recorded. Players had to confirm that they were able to take fully part in training sessions and match play.

2.5. Physical testing

After completing the sport specific questionnaire, players were physically tested for hip strength and ROM. All test procedures were conducted and standardised in the manner previously described by Mosler et al. (Fig. 1, see appendix for protocol) (Mosler et al., 2017). Testing was completed prior to training sessions, to prevent different training intensities affecting strength and ROM measures. We omitted a warming-up to reflect the way strength measurements are done in clinical practice with injured athletes, where a warming-up is not performed. All physical tests were performed at the training facility of the participating club.

2.6. Hip strength

The following tests were used to determine hip strength: eccentric hip ADD, eccentric hip ABD and the adductor squeeze test (Crow et al., 2010; Thorborg et al., 2014). Strength testing was performed using a hand-held dynamometer (MicroFET, Hoggan Scientific, Salt Lake City, USA), measuring the maximum force in Newton (N) (Tyler et al., 2001). Hip ADD and ABD strength were measured in a side-lying position with the leg being tested in a horizontal straight position (Thorborg, Couppe, Petersen, Magnusson, & Holmich, 2011). The hip and knee of the other leg were placed in 90° of flexion. Players exerted a 3 seconds maximum isometric contraction against the hand-held dynamometer, followed by a 2 seconds break test performed by the examiners to elicit the peak force (Mosler et al., 2017). For each leg, adduction and abduction strength tests were repeated three times, with the highest score used for the analysis (Mosler et al., 2017). There was a 30 seconds rest period between each attempt (Thorborg, Serner, et al., 2011). Eccentric adduction and abduction strength measures were reported as Newton-meters per kilogram body weight (Nm/kg) (Mosler et al., 2017). The adduction squeeze test was only performed once (Mosler et al., 2017), with the hand-held dynamometer placed between the knees with 45° of hip flexion (Delahunt, Kennelly, McEntee, Coughlan, & Green, 2011; Light & Thorborg, 2016). The player was asked to squeeze the knees together with maximum effort. The score was reported as Newton per kilogram (N/kg) (Mosler et al., 2017).

2.7. Hip range of motion

Hip ROM was determined by measuring maximal internal rotation, external rotation and bent knee fall out (Malliaras et al., 2009). Internal and external rotation was measured in supine

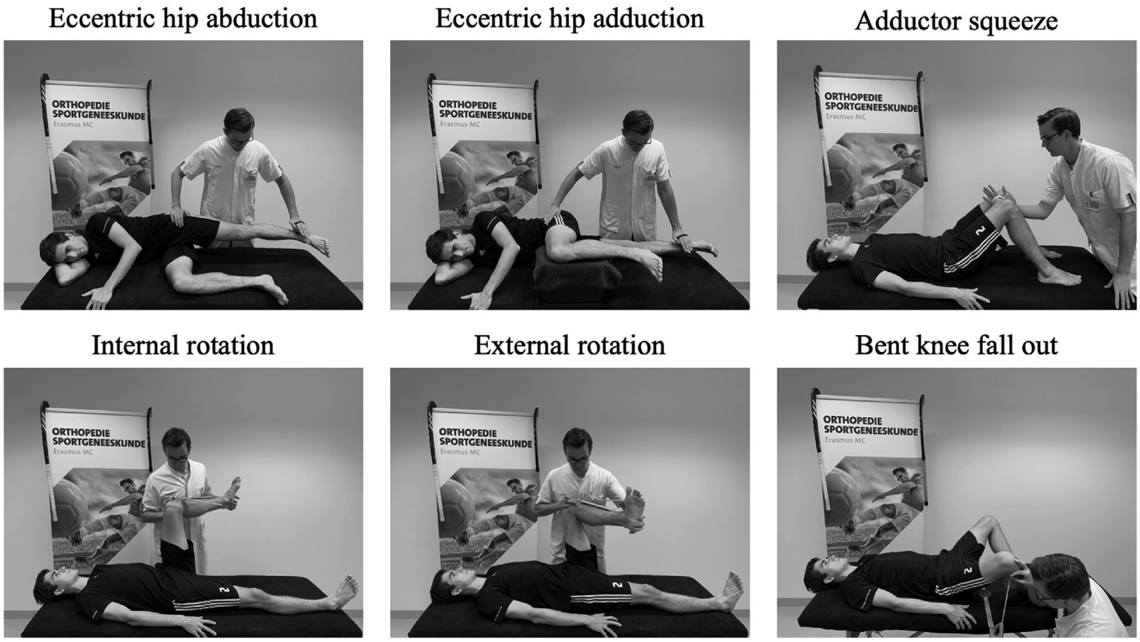

Fig. 1. Test procedures.

position with 90° of hip flexion using an extended goniometer (Nussbaumer et al., 2010). End ROM was defined as the first moment that resistance was experienced by the examiner and/or the pelvis tended to tilt laterally as lateral tilting will result in overestimation of hip rotation (Tak et al., 2017). Each measurement was performed twice and the average score was used for analysis (Mosler et al., 2017). The bent knee fall out (BKFO) was measured in a crook lying position (i.e. 45° of hip and 90° knee flexion). Players were then instructed to let their knees "fall" outwards, while keeping the soles of their feet together. At the end of ROM, little overpressure was given at both medial femoral condyles to ensure a relaxed end position. The distance from the fibular head to the top of the table was then measured in centimeters.

Table 1
Inter-rater reliability results.

	n (hips)	ICC[a]	95% CI[b]	SE[c]	CoV[d] (%)
Strength					
Adductor squeeze	30	0.52	−0.28–0.83	0.47	11.3
Eccentric ADD[e]	30	0.75	0.47–0.88	0.30	11.2
Eccentric ABD[f]	30	0.75	0.48–0.88	0.25	10.0
Range of motion					
Internal rotation	30	0.26	−0.57–0.65	6.2	19.0
External rotation	30	0.23	−0.57–0.63	7.8	16.5
BKFO[g]	30	0.93	0.85–0.97	1.4	8.9

[a] ICC = intraclass correlation coefficient (two-way mixed, average measures, absolute agreement).
[b] CI = confidence interval.
[c] SE = standard error (of the mean difference between observers).
[d] CoV = coefficient of variance.
[e] ADD = adduction.
[f] ABD = abduction.
[g] BKFO = bent knee fall out.

2.8. Inter-rater reliability

Two examiners, a medical student (TB) and a medical doctor (PK), who performed all physical tests, were trained in the methods for 15 hours by an experienced sports physician (AW). Inter-rater reliability was examined on 15 physically active men (≥2 hours of physical activity a week), aged 18–40 years, outside the testing sessions. Inter-rater reliability results for both strength and ROM measures are presented in Table 1. In addition to the Intraclass Correlation Coefficient (ICC; two-way mixed, average measures, absolute agreement) results we calculated the standard error (SE) of the difference in the measurement between the two observers (standard deviation of the mean difference between both observers divided by the square root of two as there were two observers). We also presented the coefficient of variance for the measures (standard error divided by the mean of all measures multiplied by 100).

2.9. Determining normal value profiles

After each single test attempt, any pain experienced by the player during strength testing was elicited using a 0–10 Numerical Rating Scale (NRS), where 0 represents no pain at all and 10 represents the worst pain imaginable. To ensure that normal values for strength data were not underestimated by players who exerted reduced force as result of pain during test attempts, the traffic light approach as used by Thorborg et al. was used as cut-off measurement (Thomee, 1997; Thorborg, Branci, Nielsen, Langelund, & Holmich, 2017). The traffic light approach divides NRS-scores into three groups: (1) NRS 0–2, (2) NRS 3–5 and (3) NRS 6–10. We only used group 1 and 2 (NRS 0–2 and NRS 3–5) for normal value analysis. When a player reported two NRS-scores of 6 or higher within one muscle group (i.e. adductor muscle group left, adductor muscle group right, abductor muscle group left and abductor muscle group right), this muscle group was excluded from analysis for normal values. If two NRS-scores of 6 or higher occurred within an adductor muscle group, the outcome of the adductor squeeze test was also excluded from analysis. When the NRS-score of the adductor squeeze test was reported to 6 or higher, this test was excluded from analysis for normal values.

2.10. Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics (version 25, IBM, Armonk, USA). Hip strength and ROM data were first examined for normality by using the Shapiro-Wilk Test and visual inspection of data histograms. All data was found to be normally distributed and presented as mean ± standard deviation (SD). One-way ANOVA analysis was used to assess if there were any significant differences in player characteristics (age, weight, height and body mass index (BMI)) between the playing levels and playing positions. If statistically significant differences between playing levels or playing positions occurred, post hoc analysis with Bonferroni adjustments were performed. Linear mixed model analysis was performed to investigate the effects of age, leg dominance, playing position, playing level and current presence of groin pain (non-time-loss) on hip strength and ROM measures. When a player did not have a preferred leg to kick a football, both legs were considered as dominant. Strength and ROM measures were entered as dependent variables. Leg dominance, playing position, playing level and presence of groin pain were entered as fixed factors. Age and BMI were entered as covariates. Side was entered as repeated measure. Value of p was set at < 0.05 to indicate statistical significance.

3. Results

3.1. Total number of players and exclusions

In total 104 players agreed to participate in this study. Four players were excluded from analysis; 2 players due to a groin injury, 1 player had a current ankle sprain and was therefore not able to participate in training sessions and match play for the last two weeks and 1 player because he did extensive weight training just prior to testing session. Eight players reported NRS scores of 6 or higher during strength testing, resulting in exclusion of strength measures. Fig. 2 shows the inclusion and exclusion of strength measures in the study.

3.2. Player characteristics

The player characteristics are presented in Table 2. There were no statistically significant differences found in age, weight, height and BMI between the different playing levels. However, there were significant differences in weight between the different playing positions. Post hoc tests (multiple comparisons) demonstrated that goalkeepers were heavier than defenders (mean difference = 6.7 kg, 95% CI = 0.16–13.34, p-value = 0.04) and attackers (mean difference = 6.6 kg, 95% CI = 0.19–13.09, p-value = 0.04).

The normal values for hip strength are presented in Table 3.

3.3. Age and BMI

Age did not have an effect on strength values. Higher BMI values were statistically associated with less strong hip adduction (slope = −0.1 kg/square meter, 95% CI = −0.13–0.15, p-value = 0.01) and hip abduction (slope = −0.1 kg/square meter, 95% = −0.12–0.02, p-value = < 0.01).

3.4. Leg dominance

We found no statistically significant differences between the dominant and non-dominant legs for eccentric ADD strength, ABD strength and the ADD/ABD ratio (see Table 5 in the appendix).

3.5. Playing level

There were statistically significant differences in eccentric adduction strength between playing levels. Recreational players had higher adduction strength than sub-elite players (mean difference = 0.2 Nm/kg, 95% CI = 0.08–0.46, p-value = 0.04) (see Table 6 in the appendix) as well as players from the 1st league (mean difference = 0.3 Nm/kg, 95% CI = 0.07–0.70, p-value = 0.01). Other strength measures did not differ between the playing levels.

3.6. Playing position

There was no association between different playing positions and their strength values (see Table 7 in the appendix).

3.7. Presence of groin pain

Players with non-time-loss groin pain had similar strength as asymptomatic players (see Table 8 in the appendix).

Normal values for hip range of motion.

The normal values for hip ROM are presented in Table 4.

3.8. Age and BMI

Both age and BMI did not have any significant effect on the ROM.

3.9. Leg dominance

Range of motion did not statistically differ between the dominant and non-dominant legs for external rotation and bent knee fall out. Internal rotation was significantly lower on the dominant side when compared to the non-dominant side (mean difference = 2.3°, 95% CI = 0.52–4.16, p-value = 0.12) (see Table 5).

3.10. Playing level

Range of motion values did not differ between playing levels (see Table 6).

3.11. Playing position

When comparing ROM values between different playing positions we found no statistically significant differences (see Table 7).

3.12. Presence of groin pain

There was no difference in ROM values between asymptomatic players and players with non-time-loss groin pain (see Table 8).

4. Discussion

Our study is the first to report normal values for hip strength and ROM in male field hockey players. The results further demonstrated that there were no clinically relevant differences between the dominant and non-dominant leg, the different playing positions, the different playing levels and between asymptomatic players and players with non-time-loss groin pain. Additionally, age and BMI did not have clinically relevant effects on both hip strength and ROM values. This means that the values reported here can be used in clinical practice regardless of age, BMI, leg dominance, playing position, playing level and current presence of groin pain (non-time-loss).

4.1. Hip strength

In our study we found an eccentric hip ADD value of 2.8 ± 0.4 Nm/kg. In a similar study by Mosler et al. with football players, the outcome of eccentric hip ADD was 3.0 ± 0.6 Nm/kg (Mosler et al., 2017). Another study with football players showed a similar value of 3.1 ± 0.4 Nm/kg (Thorborg et al., 2014). Adductor strength of field

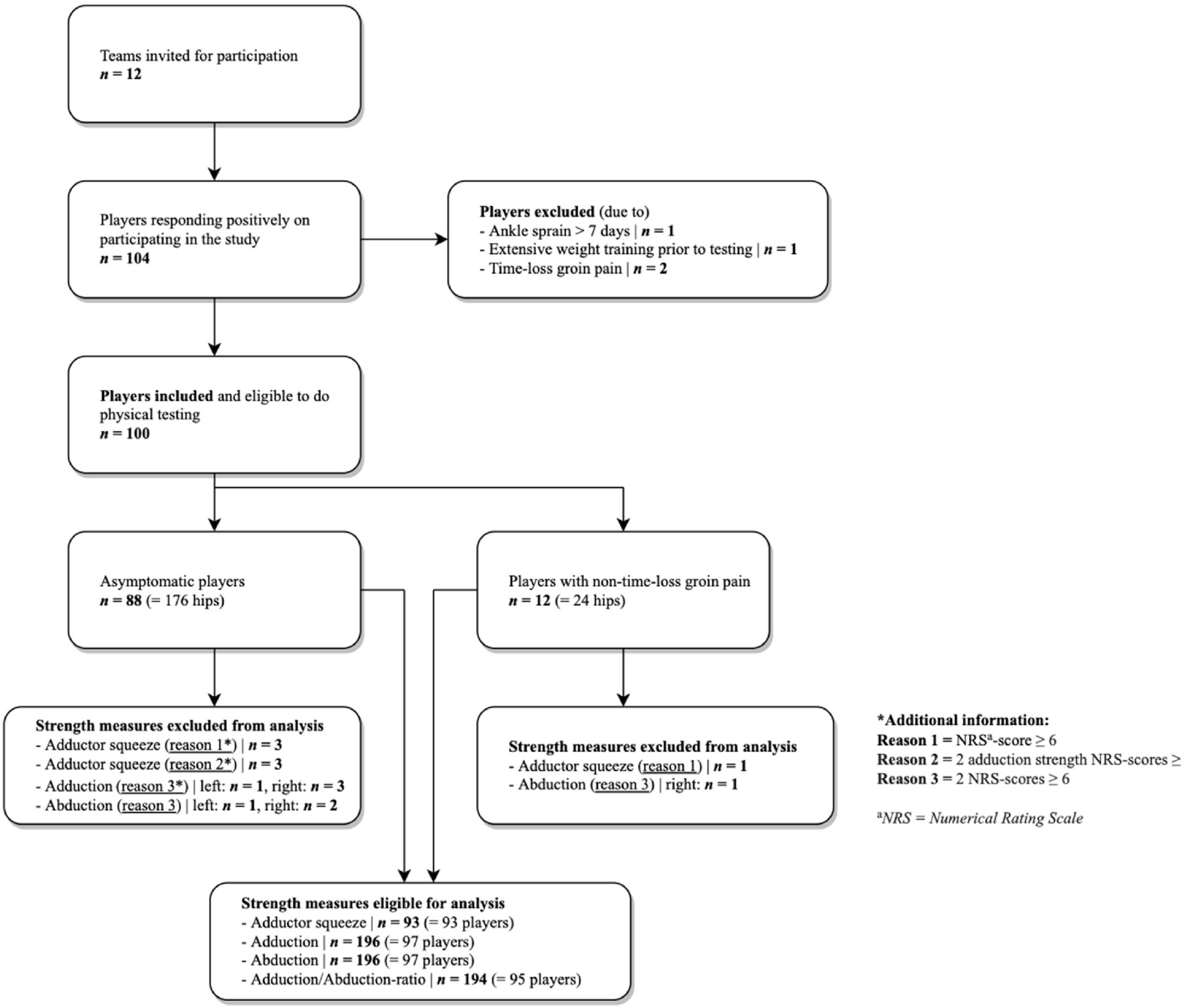

Fig. 2. Inclusion of strength data.

hockey players being slightly lower than the adductor strength of football players might lie in the reasoning that adductor muscles of field hockey players are not being exposed to kicking actions like in football eliciting peak adductor force in maximum abducted positions. The eccentric hip ABD value in our study was 2.6 ± 0.4 Nm/kg, which is in line with the findings of Mosler et al. (5). Taking the different playing levels into account, we found a statistically significant higher hip adduction value in recreational players in comparison to elite players (mean difference = 0.3 Nm/kg, 95% CI = 0.07–0.70, p-value = 0.01) and sub-elite players (mean difference = 0.2 Nm/kg, 95% CI = 0.08–0.46, p-value = 0.04). There is no clear reason why this difference in hip adduction strength reached the level of significance and as these differences did not exceed the standard error of measurement, we considered these differences not clinically relevant. It is possible that this result is a type 1 error.

The ADD/ABD strength ratio in our study was 1.1 ± 0.2. Previous studies by Mosler et al. and Tyler et al. found these ratios to be 1.2 ± 0.2 and 0.95 in football and ice hockey players respectively (Mosler et al., 2017; Tyler et al., 2001). In a study with Australian football players in which the ADD/ABD strength ration was categorised in three playing levels, the outcome values differed from 1.13 in elite players to 1.03 in amateur players. As described previously the risk profile for future groin problems may differ between sports (Mosler et al., 2017). Tyler et al. found that ice hockey players were 17 times more likely to sustain an adductor muscle strain if their ADD/ABD ratio was less 0.8 (Tyler et al., 2001). Mosler et al., found this injury rate threshold to be at 0.9 (Mosler et al., 2017). In our study the lower limit of the normal range for the ADD/ABD ratio was 1.0, and therefore field hockey players might already benefit from adductor strengthening programs if they have a ratio less than 1.0.

The outcome of the adductor squeeze test in field hockey players differed from those with football players (Mosler et al., 2017). In our study we found the mean adductor squeeze test value to be 4.5 ± 0.8 N/kg. In the study of Mosler et al. the adductor squeeze test value was 3.6 ± 0.8 N/kg. This can probably be explained by the different sport specific demands between field hockey and football. During training and match play hockey players spend more time than football players in a characteristic deep hip flexed position in a

Table 2
Player characteristics (n = 100 players).

	Mean ± SD[a]
Age (years)	23 ± 3.3
Weight (kg[b])	78 ± 7.4
Height (cm[c])	183 ± 6.1
BMI[d] (kg/m[2e])	23 ± 1.5
	n
Dominant leg	
Left	11
Right	86
No preference	3
Playing position	
Goalkeeper	12
Defender	29
Midfielder	25
Attacker	34
Playing level	
Elite (Hoofdklasse)	21
Sub-elite (Promotieklasse)	37
Amateur (Overgangsklasse)	42

[a] SD = standard deviation.
[b] kg = kilogram; [§]cm = centimeter.
[c] BMI = body mass index.
[d] kg/m^2 = kilogram per square meter.

measure is comparable with the internal rotation values found in football players (32° ± 8°) and Gaelic football players (dominant leg: 35° ± 6°, non-dominant leg: 34° ± 6°) (Mosler et al., 2017; Nevin & Delahunt, 2014). We also found slightly higher values for internal rotation in the dominant leg. Internal rotation was statistically higher for the dominant leg, than for the non-dominant leg (mean difference = 2°, 95% CI = 0.43–4.48, *p*-value = 0.02). Given that the standard error of the measurement (6.2) is larger than the difference between leg dominance we deemed this finding not to be clinically relevant.

When taking the playing position into account, we found that goalkeepers had more internal rotation than midfielders (mean difference = 11°, 95% CI = 0.21–21.21, *p*-value = 0.04). As this difference was larger than the standard error of measurement this may be clinically relevant. These differences could be explained by the fact that heavy physical load is associated with the development of cam morphology of the femoral head neck junction (van Klij et al., 2019). As goalkeepers likely have less intensive and strenuous demands on the hips compared with field players, they might not develop this morphology and resultant reduced motion. As no imaging was performed during our study this remains a hypothesis. The players in our study had 47° ± 9° of hip external

Table 3
Normal values for hip strength.

	Total	Profile Ranges				
	Mean ± SD[a]	Very low	Low	Normal	High	Very high
		(<2 SD)	(1–2 SD)		(1–2 SD)	(>2 SD)
Strength						
Squeeze (N/kg[b])	4.53 ± 0.8	<2.9	2.9–3.7	3.7–5.3	5.3–6.1	>6.1
ADD[c] (Nm/kg[d])	2.82 ± 0.4	<2.0	2.0–2.4	2.4–3.2	3.2–3.6	>3.6
ABD[e] (Nm/kg)	2.60 ± 0.4	<1.8	1.8–2.2	2.2–3.0	3.0–3.4	>3.4
ADD/ABD ratio	1.09 ± 0.1	<0.9	0.9–1.0	1.0–1.2	1.2–1.3	>1.3

[a] SD = standard deviation.
[b] N/kg = Newton per kilogram.
[c] ADD = adduction.
[d] Nm/kg = Newton meter per kilogram.
[e] ABD = abduction; squeeze: *n* = 93; adduction: *n* = 97; abduction: *n* = 97; adduction/abduction ratio: *n* = 95.

Table 4
Normal values for hip range of motion (n = 100 players).

	Total	Profile Ranges				
	Mean ± SD[a]	Very low	Low	Normal	High	Very high
		(<2 SD)	(1–2 SD)		(1–2 SD)	(>2 SD)
Range of motion						
Internal rotation (°[b])	34 ± 11	<12	12–23	23–45	45–56	>56
External rotation (°)	47 ± 9	<29	29–38	38–56	56–65	>65
BKFO[c] (cm[d])	15 ± 4	<7	7–11	11–19	19–23	>23

[a] SD = standard deviation.
[b] ° = degrees.
[c] BKFO = bent knee fall out.
[d] cm = centimeter.

wide stance. Hence, this may lead to hockey players being stronger in adduction when their hips are flexed in comparison with football players when tested with squeeze.

We found that our strength measures had a good inter-rater reliability (Koo & Li, 2016).

4.2. Hip range of motion

In our study we found internal rotation to be 34° ± 11°. This

rotation. This is substantially higher than previous observations of external rotation measures amongst football players (38° ± 8°) and Gaelic football players (30° ± 5°) (Mosler et al., 2017; Nevin & Delahunt, 2014). The reason for this difference is unclear and we cannot think of a simple explanation for this. There was no statistically significant difference found in leg dominance, playing position, playing level and current presence of groin pain.

The BKFO in our study for hockey players was 14.9 ± 4.3 cm. This is comparable to football players, who showed a BKFO of

13 ± 4.4 cm. Gaelic football players also showed similar measures (dominant leg: 15.1, non-dominant leg: 15.2) (Mosler et al., 2017; Nevin & Delahunt, 2014). Again, there was no statistically significant difference found in leg dominance, playing position, playing level and current presence of groin pain. It is unclear why the external rotation was larger in the hockey players and yet the BKFO was similar. The BKFO test contains a degree of external rotation but may also be limited by the adductor muscle group. It seems these two tests measure different aspects.

BKFO measures had a good inter-rater reliability (Koo & Li, 2016). However, internal and external rotation measures were less reliable. This is in accordance with other studies (Poulsen et al., 2012; Prather et al., 2010; van Trijffel, van de Pol, Oostendorp, & Lucas, 2010), which impedes the clinical appreciation of hip ROM in general.

4.3. Strengths and limitations

Our study has several strengths. We examined a large population of 104 male field hockey players. This number is divided into three different playing levels. The number of individuals in each category is in line with another study among Australian football players (Prendergast et al., 2016). In order to perform this study, we used a protocol used by Mosler et al. and Thorborg et al. (Mosler et al., 2017; Thorborg, Couppe, et al., 2011) We practiced extensively with this protocol before carrying out the actual testing sessions. We measured hip strength by using a hand-held dynamometer and measured range of motion with a goniometer in supine position. Both tests were performed without any additional stabilisation equipment like belts. Additional stabilisation may have improved the repeatability of the measurements. However, it is not common practice to take this kind of measures as clinicians favor a swift execution of the physical tests. Secondly, selection bias may have occurred in our study. We invited a large number of teams to participate in this study, however due to various limited time schedules of field hockey teams and players (important matches in the national and international leagues, work/study of players and/or other commitments), we had to be logistically efficient in the definite choice of available teams and players. In this study we only documented the normal values for male field players. As such these normal values may not be applicable for female field hockey players. Finally, the single observer method of measuring hip ROM did not have good reliability in our study.

5. Conclusion

Our study presents normal values for hip strength and ROM for field hockey players, which clearly differ in some aspects from other sports. Leg dominance, playing position, playing level and the current presence of groin pain (non-time-loss) did not have a clinically relevant influence on hip strength and ROM values.

Ethical approval

Approval of the Medical Research Ethics Committee Erasmus MC was obtained (MED-2018-1576) and all athletes provided their written informed consent.

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Declaration of competing interest

None declared.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2020.08.014.

APPENDIX

Table 5
Normal values for hip strength and range of motion ($n = 200$ hips) – *Leg dominance*

	Dominant	Non-dominant		
	($n = 103$)	($n = 97$)		
	Mean ± SD[a]	Mean ± SD	Mean difference	*p*-value
Strength				
Squeeze (N/kg[b])	4.53 ± 0.5			
ADD[c] (Nm/kg[d])	2.82 ± 0.4	2.80 ± 0.4	0.02	0.554
ABD[e] (Nm/kg)	2.59 ± 0.4	2.60 ± 0.4	0.01	0.707
ADD/ABD ratio	1.10 ± 0.2	1.09 ± 0.2	0.01	0.618
Range of motion				
Internal rotation (°[f])	33.1 ± 12.3	35.5 ± 11.7	2.34	0.012
External rotation (°)	47.4 ± 9.8	46.1 ± 9.0	1.28	0.144
BKFO[g] (cm[h])	14.8 ± 4.7	15.1 ± 4.3	0.308	0.222

[a] SD = standard deviation.
[b] N/kg = Newton per kilogram.
[c] ADD = adduction.
[d] Nm/kg = Newton meter per kilogram.
[e] ABD = abduction.
[f] ° = degrees.
[g] BKFO = bent knee fall out.
[h] cm = centimeter.

Table 6
Normal values for hip strength and range of motion ($n = 100$ players) – *Playing level*

	Elite	Sub-elite	Amateur	*p*-value
	($n = 21$)	($n = 37$)	($n = 42$)	
	Mean ± SD[a]	Mean ± SD	Mean ± SD	
Strength				
Squeeze (N/kg[b])	4.61 ± 1.6	4.31 ± 1.2	4.68 ± 1.1	0.098
ADD[c] (Nm/kg[d])	2.63 ± 0.9	2.73 ± 0.7	2.96 ± 0.6	0.050
ABD[e] (Nm/kg)	2.48 ± 0.8	2.61 ± 0.6	2.64 ± 0.5	0.257
ADD/ABD ratio	1.07 ± 0.3	1.06 ± 0.2	1.13 ± 0.2	0.095
Range of motion				
Internal rotation (°[f])	37.0 ± 24.5	33.2 ± 18.4	34.8 ± 17.4	0.457
External rotation (°)	49.4 ± 18.4	45.4 ± 13.8	46.4 ± 13.0	0.215
BKFO[g] (cm[h])	14.2 ± 9.4	14.9 ± 7.1	15.6 ± 6.7	0.496

[a] SD = standard deviation.
[b] N/kg = Newton per kilogram.
[c] ADD = adduction.
[d] Nm/kg = Newton meter per kilogram.
[e] ABD = abduction.
[f] ° = degrees.
[g] BKFO = bent knee fall out.
[h] cm = centimeter.

Table 8
Normal values for hip strength and range of motion ($n = 200$ hips) – *Asymptomatic / NTL*[a]

	Asymptomatic	NTL groin pain		
	(n = 185)	(n = 15)		
	Mean ± SD[b]	Mean ± SD	Mean difference	p-value
Strength				
Squeeze (N/kg[c])	4.53 ± 0.8	4.53 ± 0.8	<0.01	>0.999
ADD[d] (Nm/kg[e])	2.82 ± 0.4	2.73 ± 1.0	0.08	0.388
ABD[f] (Nm/kg)	2.60 ± 0.4	2.52 ± 0.9	0.08	0.361
ADD/ABD ratio	1.10 ± 0.1	1.04 ± 0.4	0.05	0.241
Range of motion				
Internal rotation (°[g])	34.8 ± 11.1	31.1 ± 27.1	3.7	0.168
External rotation (°)	46.6 ± 8.5	46.4 ± 23.0	0.2	0.931
BKFO[h] (cm[i])	15.0 ± 4.3	15.2 ± 8.3	0.1	0.857

[a] NTL = non-time-loss.
[b] SD = standard deviation.
[c] N/kg = Newton per kilogram.
[d] ADD = adduction.
[e] Nm/kg = Newton meter per kilogram.
[f] ABD = abduction.
[g] ° = degrees.
[h] BKFO = bent knee fall out.
[i] cm = centimeter.

Table 7
Normal values for hip strength and range of motion ($n = 100$ players) – *Playing position*

	Goalkeeper	Defender	Midfielder	Attacker	p-value
	(n = 12)	(n = 29)	(n = 25)	(n = 34)	
	Mean ± SD[a]	Mean ± SD	Mean ± SD	Mean ± SD	
Strength					
Squeeze (N/kg[b])	4.86 ± 2.1	4.71 ± 1.3	4.31 ± 1.4	4.40 ± 14	0.075
ADD[c] (Nm/kg[d])	2.93 ± 1.2	2.94 ± 0.8	2.79 ± 0.8	2.66 ± 0.7	0.054
ABD[e] (Nm/kg)	2.60 ± 1.0	2.69 ± 0.7	2.56 ± 0.7	2.53 ± 0.6	0.323
ADD/ABD ratio	1.12 ± 0.4	1.11 ± 0.3	1.11 ± 0.3	1.05 ± 0.3	0.351
Range of motion					
Internal rotation (°[f])	42.1 ± 32.3	34.6 ± 20.3	31.4 ± 21.6	37.6 ± 18.9	0.062
External rotation (°)	47.6 ± 24.9	44.1 ± 15.7	47.1 ± 16.7	48.1 ± 14.6	0.283
BKFO[g] (cm[h])	15.8 ± 12.7	15.5 ± 8.0	15.1 ± 8.5	14.3 ± 7.5	0.075

[a] SD = standard deviation.
[b] N/kg = Newton per kilogram.
[c] ADD = adduction.
[d] Nm/kg = Newton meter per kilogram.
[e] ABD = abduction.
[f] ° = degrees.
[g] BKFO = bent knee fall out.
[h] cm = centimeter.

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