ACKNOWLEDGEMENTS

This master thesis was accomplished after a period of two intensive years of research and working. We would like to thank everyone who has contributed to or has been involved with the development of our master thesis.

First of all, a special thanks to our promoter Prof. Dr. Bert Op ’t Eijnde and co-promoter Drs. Charly Keytsman for their advice, input, support and guidance during these two years of work. We would also like to thank ADLON, Sports Medical Center of Hasselt University, and REVAL for providing us with the opportunity to make use of the BIODEX® device and the DEXA scan. In particular, we would like to thank Anne Bogaers for the time she made to take the DEXA scans and Dr. Pieter Van Noten who taught us how to use the BIODEX® device and guided us through the first measurements.

A huge thanks to all the participants who made time to contribute to our study, especially the medical-, technical staff and players of STVV who implemented the BIODEX® measurements in their busy pre-season training program.

Furthermore, we wish to thank UHasselt for the five years of education in Rehabilitation sciences and physical therapy and the opportunity to participate in this very interesting master thesis.

Lastly, we would like to thank our family and friends for being supportive during our entire study time at UHasselt.

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RESEARCH CONTEXT

This master thesis is part of the master's program "Rehabilitation sciences and Physiotherapy" and was performed in the REVAL Rehabilitation Research Center and ADLON Sports Medical Center of Hasselt University. Here, injury prevention and sport performance enhancement amongst others in professional athletes, recreational athletes and even pathological populations are investigated. Soccer, the most popular sport in the world[1-3], is associated with a high risk of injury ultimately leading to the inability to play matches and perform training sessions.[4-5] Hamstrings, adductors and quadriceps are the most commonly injured muscles in soccer.[6] With respect to soccer performance, muscle strength and the performance of a soccer player are correlated extremely positive.[7-8] Because the level of soccer expertise may determine muscle strength, and vice versa, this project aims to investigate the differences in muscle strength of the abovementioned muscle groups, their antagonists and their more proximal stabilizers such as the trunk flexors/extensors in elite soccer players, amateur soccer players and sedentary controls. As such, comparison of normalized upper leg and trunk muscle strength values or ratios of soccer players with norm values is possible. Therefore, a second aim of this project was to describe norm values of these muscle groups.

This thesis consists of two parts. The first part was conducted during the academic year 2016-2017 and involved a literature review of the existing researches regarding this topic. The purpose was to collect norm values of and ratios between professional- and amateur soccer players and sedentary controls. Based on this literature review, we concluded that there already existed H/Q ratios for soccer players. Non-soccer specific ratios were published for trunk flexor and extensor muscles and hip ab- or adductors. Moreover, norm values could not be set because of different measurement techniques and protocols. Strength values relative to fat free mass (FFM) were, to our knowledge, only investigated in a few soccer specific studies.[9] During the second part (academic year 2017-2018) we investigated the impact of the level of expertise of the soccer player on muscle strength values relative to FFM in comparison with sedentary controls. As such, the following research question was set up notably 'Does the level of expertise of soccer players affects muscle strength in comparison with sedentary controls?' All measurements were performed using standardized devices such as BIODEX® dynamometer for strength measurements and DEXA scans for body composition.

This present project is not part of an ongoing REVAL research project and was performed at Hasselt University, Diepenbeek. The promoter, Prof. Dr. Bert Op ‘t Eijnde, proposed to investigate this topic. The first part was executed as a part of the first master year rehabilitation sciences and physiotherapy. Similarly, to the first part, the second part took place in Diepenbeek and was executed as a part of the second master year rehabilitation sciences and physiotherapy. Both parts were executed at the research center REVAL of Hasselt University in collaboration with ADLON Sports Medical Advice Center and under the supervision of Prof. Dr. Bert Op ‘t Eijnde and Drs. Charly Keytsman.

This research aimed to include ~20 male elite soccer players (first division: STVV), ~20 amateur soccer players (third and fourth provincial: Genker VV and KFC Zwartberg) and ~20 sedentary controls with a BMI between 18 and 25. All measurements were executed in one day and under supervision of an examiner. First, participants underwent a DEXA scan to measure their body composition (e.g. fat free mass). Hereafter, trunk flexor/extensor and hip adductor/abductor and knee flexor/extensor, hip adductor/abductor and knee flexor/extensor strength was evaluated using a BIODEX® dynamometer.

All parts of this master thesis (design, methods, data-acquisition, statistical analysis and academic writing) were produced by the students under supervision of the promoter. In agreement with the promoter, the United States National Library of Medicine (the NLM style) format was chosen as the reference style.

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TABLE OF CONTENTS

TRUNK AND LOWER BODY MUSCLE STRENGTH IN SOCCER

1. ABSTRACT

Background: Soccer involves intermittent physical activity during high intensity short action sequences requiring numerous skills such as tackling, kicking, etc. This requires adequate lower limb and trunk muscle strength. Norm values of quadriceps/hamstrings, hip abductor/adductor and trunk flexors/extensors for elite and amateur soccer players in comparison to sedentary controls however are unclear.

Objectives: The objective of this study was to compare muscle strength values and ratios of the abovementioned muscle groups between elite-, amateur soccer players and sedentary controls and to normalize these values by using the fat free mass.

Participants: Inclusion criteria: >16 years old, understanding Dutch, English or French. Elite soccer players (Jupiler Pro League), amateur soccer players (3^{th}-4^{th} provincial) and sedentary controls (BMI 18-25 and no sport). Exclusion criteria: injuries during the last 12m that may affect muscle strength, <40 years old.

Measurements: Isokinetic (knee) and isometric (trunk, hip and knee) measurements were performed using a BIODEX® dynamometer while body composition was measured using DEXA. Participants signed an informed consent before measurements.

Results: Elite players have a lower fat mass and a higher fat free mass compared to amateur players and sedentary controls. Additionally, they show higher values trunk extension in the semi-standing position (vs. amateur soccer players ranging from 18.4% to 22.0% difference) and isokinetic knee flexion (vs. sedentary controls ranging from 15.7% to 32.8% difference) for all relative strength measurements (TBW, FFM and FFM of the limb). All of the other measurements were not significantly different between groups.

Conclusion: It can be concluded that elite players can generate strength more efficiently for trunk extension in the semi-standing position (vs. amateur players) and isokinetic knee flexion (vs. sedentary controls).

2. INTRODUCTION

Soccer is the most popular sport in the world involving ~265 million players in over 200 countries.[1] Cardiorespiratory endurance together with muscular strength are important performance variables for a soccer player. During a soccer match, elite soccer players perform short periods of high-intensity activities alternated with longer low intensity periods. These high-intensity activities consist of numerous explosive bursts.[2] High muscle strength of trunk and lower limb is required in jumping, kicking, tackling, cutting, duels and running. Up until now, and apart from e.g. exercise capacity, whole body muscle strength and power are increasingly being considered as important parameters that contribute to the quality of a soccer player. In keeping with the above line of reasoning, a better understanding of muscle function/strength in soccer **(1)** may prevent injuries and **(2)** may be a good tool to improve performance in case abnormal results are detected in e.g. an individual player. **(1)** Most common muscle injuries in professional soccer involve the hamstrings, adductors and quadriceps muscles.[3] Here, strength training regimens have been shown to reduce the number of injuries by ~50%.[4] **(2)** Furthermore, increasing lower limb muscle strength improves acceleration and speed in skills critical to soccer such as turning, sprinting and changing pace.[5] The hamstring to quadriceps ratio expresses maximal hamstring strength relative to maximal quadriceps strength. It is known that reduced hamstring to quadriceps ratio may contribute to reduced soccer performance and may also predispose athletes to hamstring and ACL-injuries.[5-17] Compared to amateur players, elite soccer players exhibit higher trunk strength (flexion, extension, lateral flexion and rotation).[18] Compared to non-athletes, soccer players have significant greater cross sectional areas of the rectus abdominis, transversus abdominis and oblique muscles.[19-20] This is associated with higher muscle strength in the latter muscles. Generally, adductor strength in soccer players is higher than abductor strength.[21-26] Interestingly, there is some evidence (in ice hockey players) that suggests that preseason hip adductor weakness, relative to abductor strength, is a predictor of future adductor strain.[27]

Despite the fact that muscle strength in soccer is rapidly becoming an important research area it is clear that several methodological issues need to be addressed. First, the applied measurement techniques and protocols to determine muscle strength in soccer players vary substantially. Although isokinetic dynamometry (e.g. BIODEX®/CYBEX®) is considered the 'golden standard' to assess various muscle strength parameters.[28-29] Muscle strength of especially trunk flexors/extensors and hip abductors/adductors have been measured using a range of, very often, not validated measurement tools. Quadriceps and hamstrings muscle strength is usually assessed using BIODEX® or CYBEX® dynamometry[5-17] but, very often, in these muscle groups the applied measurement protocols vary substantially. Consequently, it is difficult to draw solid conclusions with respect to trunk flexors/extensors and hip abductors/adductors strength in soccer and quadriceps/hamstrings ratio results are conflicting. A second methodological aspect that needs clarification is the use of normalized muscle strength. Usually, muscle strength is expressed relative to whole body weight.[18,21-24,30-31] This is functionally very relevant but of course expressing muscle strength relative to fat free mass using e.g. DEXA scan measurements is much more specific because only functional muscle mass is considered. Portella et al. (2014) was the only study that normalized maximal muscle strength to fat free mass by means of a DEXA scan in soccer players and recommends further research. Finally, to date the impact of the level of expertise on muscle strength in soccer is unclear. Quadriceps-hamstrings strength in elite vs. amateur players has been investigated by a few studies but results of these different studies are conflicting.[5,32-34] Elite hip abductor/adductor and trunk flexors/extensors strength in comparison with amateur soccer players and non-athletes has not been explored yet. In accordance with the above line of reasoning, the present study aims to investigate differences in absolute and relative strength values and ratios for trunk, hip and thigh between elite soccer players, amateur soccer players and sedentary controls. Relative strength values would be described relative to total body weight (TBW), fat free mass (FFM) and FFM of the measured limb. The hypothesis was that elite soccer players will have higher absolute and relative strength values compared to amateur soccer players and sedentary controls, due to more specific training sessions and additional strength training. A smaller difference in strength values between amateur soccer players and sedentary controls is expected.

3. METHODS

3.1 Medical ethics

The study proposal was approved by the medical ethics committee of the Jessa Hospital and the medical ethics committee of the university of Hasselt.

Number: B9115201732830

Date: 21/06/2017

3.2 Participants

This explorative study evaluated maximal muscle strength of three different populations. The present study evaluated muscle strength of elite soccer players (n=20, 1st and 2nd division) and amateur soccer players (n=11, lower regional level). A third sedentary control group (n=17) with a BMI between 18 and 25 (no sports exhibition) was added to the study. All participants were informed about the intention, the design of the study and signed an informed consent.

Table 1

Demographic data of the participants

	Elite soccer players (n=20)	**Amateur soccer players (n=11)**	**Sedentary controls (n=17)**
Age	22,8 ± 3,7	21,5 ± 2,5	21,3 ± 3,5
BMI	23 ± 1,5	22,9 ± 1,9	22,9 ± 2,4
Mass (kg)	75,5 ± 7,5	73,9 ± 5,5	73,7 ± 9,2
Fat (%)	7,6 ± 1,8	9,9 ± 2,9*	14 ± 5,1*†
FFM total (kg)	62,9 ± 5,6	59,8 ± 4,9	55,8 ± 6,5*
FFM leg (kg)	10,5 ± 1,1	9,7 ± 0,9	8,8 ± 1,1*
FFM trunk (kg)	31,1 ± 2,7	29,9 ± 2,4	27,7 ± 3,5*

[a] BMI, Body Mass Index. FFM, Fat free mass

[b] *, significant difference relative to elite soccer players. †, significant difference between amateur soccer players and sedentary controls.

[c] Significance level 0,05

3.3 Inclusion criteria

Inclusion criteria on admission were separated between the three observational groups. Common inclusion criteria were: men aged at least 16 years old and understanding English, Dutch or French. For elite soccer players inclusion criteria were: playing in Jupiler Pro League, first amateur league (2nd division, Belgium) or Eredivisie. For amateur soccer players inclusion criteria were: playing in 3rd or 4th provincial league. Inclusion criteria for the sedentary group were: no sport exhibition, BMI between 18 – 25.

3.4 Exclusion criteria

Exclusion criteria for this study were injuries that could affect muscle strength such as ACL injury in the current season, quadriceps/hamstring/adductor/abductor/abdominal/back muscle injury and low back pain.

3.5 Recruitment

Both professional and amateur soccer players were recruited from regional soccer clubs using a recruitment letter. Differentiation was made by the division in which the soccer team competes. The control subjects were recruited by means of flyers and social media.

4. TECHNICAL INFORMATION

4.1 Procedure

All measurements were performed at the REVAL rehabilitation research center (Hasselt University, Diepenbeek, Belgium) and were executed in one day. Prior to the tests, information about the demographics of the participants was obtained by a DEXA scan. After the DEXA scan, the participants started with a warm up consisting of 10- min cycling on a bicycle ergometer and minimal strength exercises for the muscles that will be tested. All measurements were executed under the supervision of an examiner. After the warm up, the participant took place in the BIODEX® device. At first, muscles in both legs were tested (quadriceps, hamstrings, ab-/adductor). After these tests the assessors changed the BIODEX® chair for the final measurements, being trunk strength.

4.1.1 Maximal strength of quadriceps/hamstrings

Participants took place on the dynamometer chair with a hip angle of 90°. The motor axis was visually aligned with the axis of the knee joint. Subjects were stabilized by straps so that only the tested knee was moving with a single degree of freedom. The shin brace of the dynamometer was placed ~2 cm above the medial malleolus, anterior to the shank for knee extension and flexion contractions. During knee contractions, a plastic shin pad, lined with 2 mm of high-density foam, was tightly secured to the tibia to avoid any discomfort to the shin during maximum contractions. Torques were gravity-corrected and standardized verbal encouragement was given by the investigator. All participants completed the assessment sequence in the same order.

A submaximal familiarization repetition was completed immediately before strength exercise (80%). For assessment of isometric peak torque of each muscle group, participants performed 1 set of 2 maximum contractions at 2 different joint angles (45° and 90°). Participants were instructed to “push” or “pull” as hard as possible for 4s. 30s rest was given between each contraction. Isokinetic muscle strength consisted of maximal concentric contraction of the quadriceps and hamstring muscles at 180°/s. The subjects were asked to extend and to flex the knee maximally through 70° ROM, starting from 90° of flexion to 160°. One trial consisting of 20 contractions was performed. The highest peak torque values and muscle fatigue of the flexors and extensors were used in the analysis. The H/Q ratio was given as Hcon/Qcon, at the corresponding angular velocity.

4.1.2 Maximal strength of hip abductor-adductor

Hip abductors and adductors were tested isometrically in a standing position. The tested leg was fixated to the dynamometer with a strap that was placed ~2 cm above the lateral epicondyle of the femur. The foot was held off the ground to make sure they could not use it to influence the measurement. Participants were placed with the anterior superior iliac spine of the tested hip directly in front of the axis of rotation. To prevent that participants would compensate with their trunk, they were instructed to support themselves by using the opposing arm to the tested leg by placing it on top of the isokinetic dynamometer and to move their trunk as little as possible. This way, the measured strength mostly originated from the hip abductors/adductors. The measurements were performed in 30 degrees of abduction. Before the actual measurement, the participant performed one trial repetition in each direction to get familiar with the measurement. After this, the investigator asked them to abduct and adduct their leg two times alternately in each direction with a maximal force.

4.1.3 Maximal strength of trunk flexors/extensors

Trunk measurements were performed in two positions notably, in semi-standing position and in 90° flexion or lumbar position. Only peak isometric torque of each muscle group (flexion/extension) was tested. Participants took place in the BIODEX® chair and were stabilized with two diagonal straps across their torso and three straps over their waist. A standardized position was based on the most cranial part of the iliac crest (height of the chair) and the spina scapulae. Furthermore, knees were fixed firmly in both positions. Participants were able to do a familiarization repetition to understand the exact movement. In the semi-standing position, there was more influence of the hip musculature, this because the hip angle was larger than 90°. In contrast, in the 90° flexion position, the delivered force came directly from the trunk musculature. The participant had to flex and extend their trunk maximally three times alternately for 4s. The investigator instructed participants by “push” and “pull” and accentuated that participants had to start slowly, build up to a maximal strength and release slowly.

4.1.4 Body composition

BMI, whole body fat, fat free mass, percentage fat, height and weight were obtained using Dual Energy X-ray Absorptiometry Scan (DEXA). By means of these values it was possible to measure strength relative to whole body mass, fat free mass, and also per region individually. This scan lasted approximately 10 minutes. With this test, other demographic information was asked such as: date of birth and age.

4.2 Primary outcome measures

The primary outcome measure of this observational study was maximal muscle strength of the trunk flexors and –extensors, hip abductors and –adductors and hamstrings/quadriceps in elite soccer players, amateur soccer players and sedentary controls.

4.3 Secondary outcome measures

The secondary outcome measure of this research was body composition of three different groups (elite soccer players, amateur soccer players and sedentary controls) measured by means of a DEXA scan. Not only total fat free mass was determined, but also fat free mass of each limb separate and fat mass. Hence, maximal muscle strength was expressed relative to fat free mass of each limb separate. This is the most specific way to express maximal muscle strength. A third outcome measure was the difference between the levels of expertise in soccer. Three different populations were included in this study. This way, we investigated the influence of the level of expertise in soccer on muscle strength in the included muscle groups.

5. STATISTICS

All data was analyzed using JMP Pro 13.2.0 (64-bit). For each outcome measurement, a one-way analysis of variance (ANOVA) was used to examine differences between groups in absolute muscle strength (hamstrings, quadriceps, hip adductors, -abductors, trunk flexors and -extensors), relative to whole body mass, relative to total fat free mass and relative to fat free mass of the measured limb. The Shapiro-Wilk test was used to assess normal distribution of the residuals. Homoscedasticity was assessed by using the Brown-Forsythe test. In order to locate differences between groups, a Tukey's test was performed post-hoc when significance was reached. In case of the absence of normal distribution and/or homoscedasticity, a non-parametric Wilcoxon test was performed. In this case, if significance was reached, a nonparametric multiple comparisons test using the Wilcoxon method was executed. All data were presented as means with standard deviation (SD) and statistical significance was set at $p<0.05$.

6. RESULTS

6.1 Primary outcome measures

6.1.1 Trunk flexion-extension

In the semi-standing position trunk extension strength of elite soccer players (342.9 ± 55.1 Nm) was 24.1% higher compared to amateur soccer players (276.2 ± 56.3 Nm) (p=0.02) and 20.6% higher compared to sedentary controls (284.3 ± 74.4 Nm) (p=0.02). Furthermore, elite soccer players trunk flexion strength (206.5 ± 30.3 Nm) was 17.5% higher compared to sedentary controls (175.7 ± 33.8 Nm) (p=0.012). In the lumbar position, trunk flexion strength of elite soccer players (205.6 ± 30.6 Nm) was 12.5% higher compared to amateur soccer players (182.8 ± 24.9 Nm; p=0.02) and 20,7% higher compared to sedentary controls (170.3 ± 38.1 Nm) (p=0.004, Figure 1). No significant differences were found between the three groups for trunk isometric strength ratios (Figure 2).

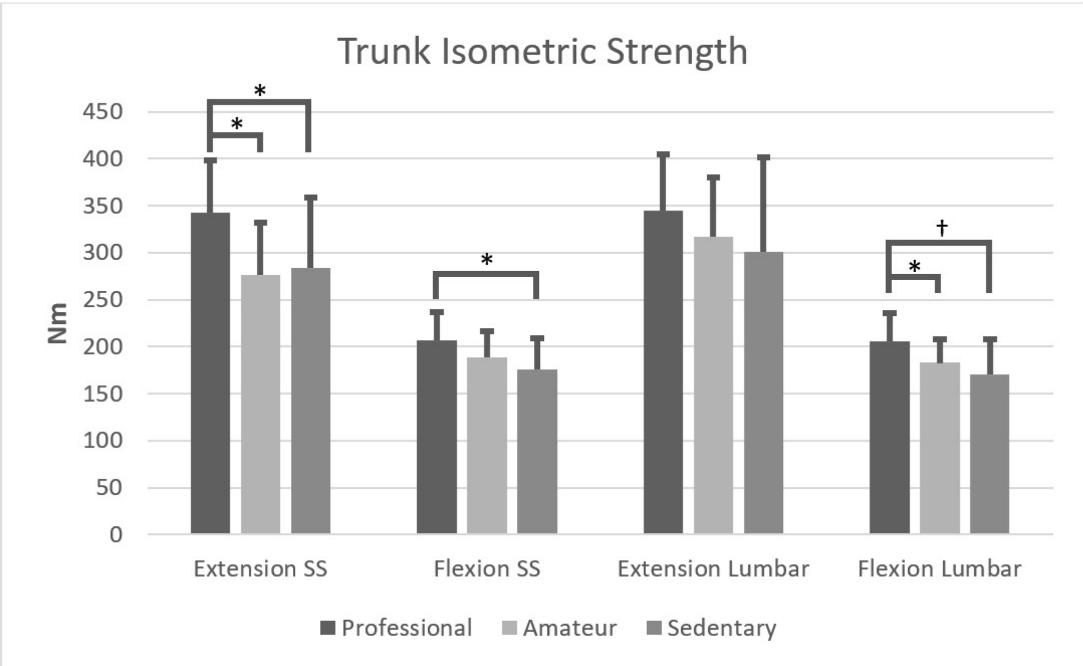

Figure 1. Trunk isometric strength (Nm). Data are means ± SD's and represent absolute isometric extension and flexion trunk muscle strength expressed in Nm of professional and amateur soccer players and sedentary persons.

[a] *, p<0.05. †, p<0.01

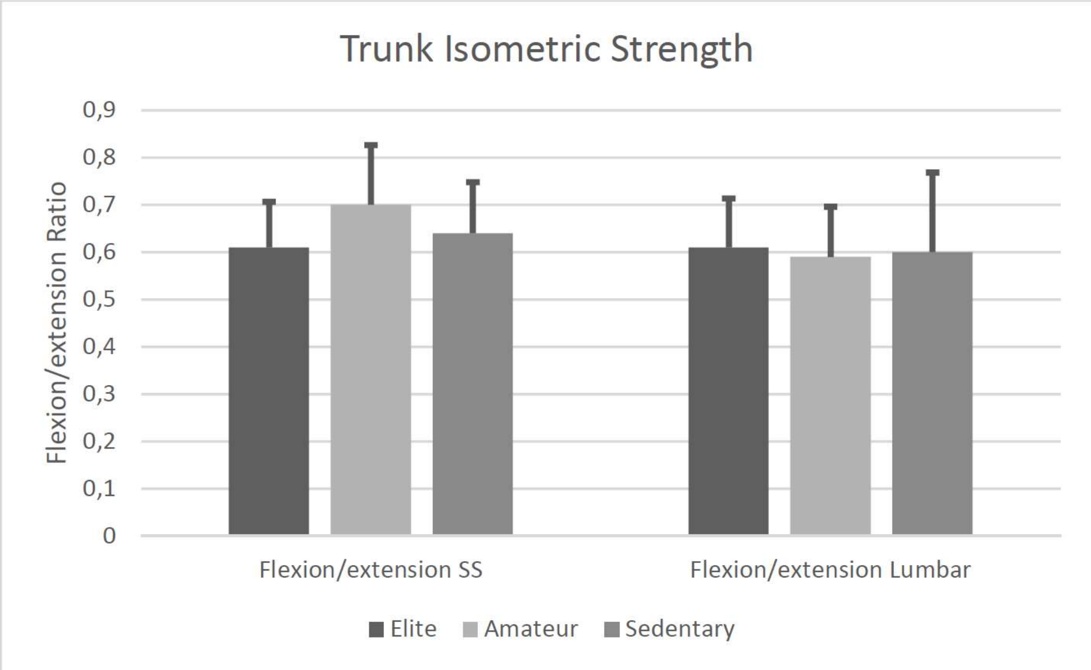

Figure 2. Trunk flexion/extension ratio. Data represent means ± SD's of trunk isometric flexion/extension ratio's in the semi-standing and lumbar position of professional and amateur soccer players and sedentary persons.

6.1.2 Hip abduction-adduction

No significant differences were found between the three groups for isometric hip abduction- and adduction strength, nor for the adduction/abduction ratio (Figure 3-4).

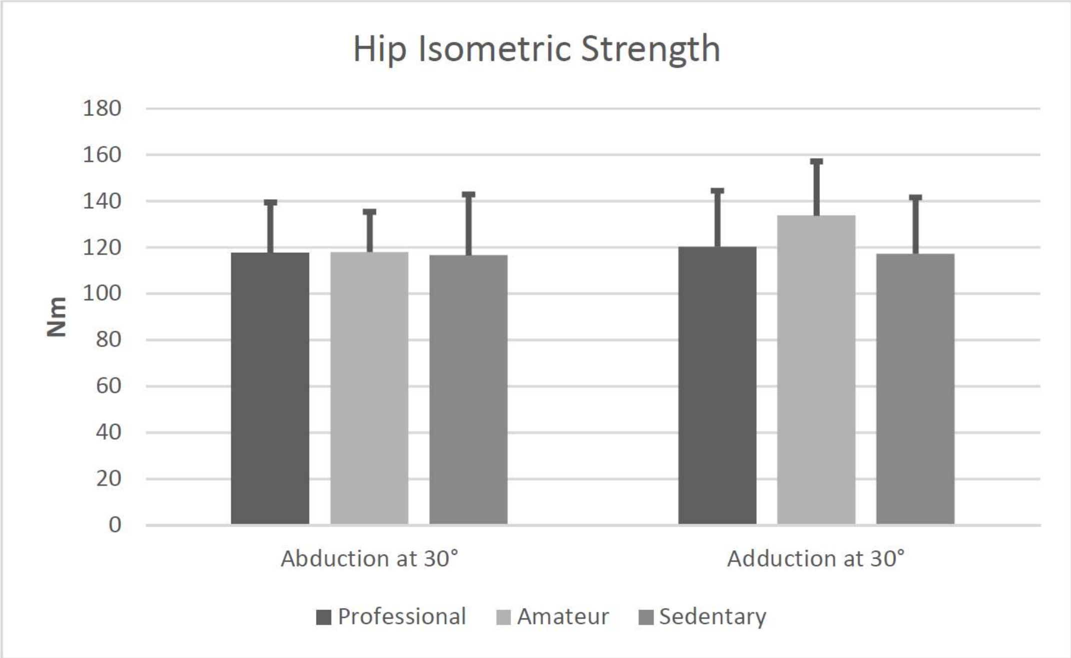

Figure 3. Hip isometric strength (Nm). Data are means ± SD's and represent absolute isometric abduction and adduction muscle strength in 30° abduction, expressed in Nm of professional and amateur soccer players and sedentary persons.

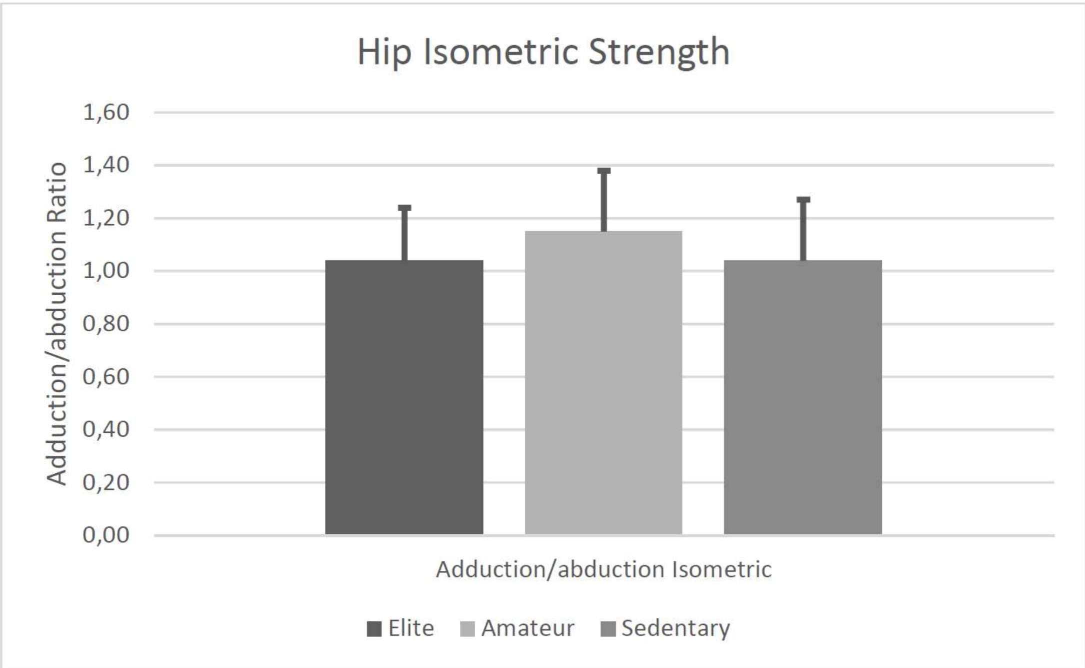

Figure 4. Hip adduction/abduction ratio. Data are mean ratio's ± SD's of isometric adduction and abduction muscle strength of professional and amateur soccer players and sedentary persons.

6.1.3 Knee flexion-extension

Isometric knee extension and flexion (229.0 ± 39.7 Nm and 145.8 ± 30.9 Nm) strength of elite soccer players at a 45° angle was 20.3% higher for extension (p=0.02) and 21.6% higher for flexion (p=0.011) compared to sedentary controls (190.4 ± 46.8 Nm and 119.9 ± 25.6 Nm, respectively). No statistic differences between groups were found at a 90° angle. Isokinetic extension of elite soccer players (190.8 ± 31.8 Nm) was 25.1% higher compared to sedentary controls (152.5 ± 27.7 Nm) (p=0.0005). Isokinetic knee flexion strength of elite soccer players (129.1 ± 20.8 Nm) was 18.7% higher compared to amateur soccer players (108.8 ± 13.7 Nm) (p=0.02) and 37.5% higher compared to sedentary controls (93.9 ± 21.5 Nm) (p<0.0001). (Figure 5-6)

No significant differences were found between the three groups for isometric or isokinetic H/Q ratios, nor were there any significant differences concerning knee muscle fatigue. (Figure 7-9)

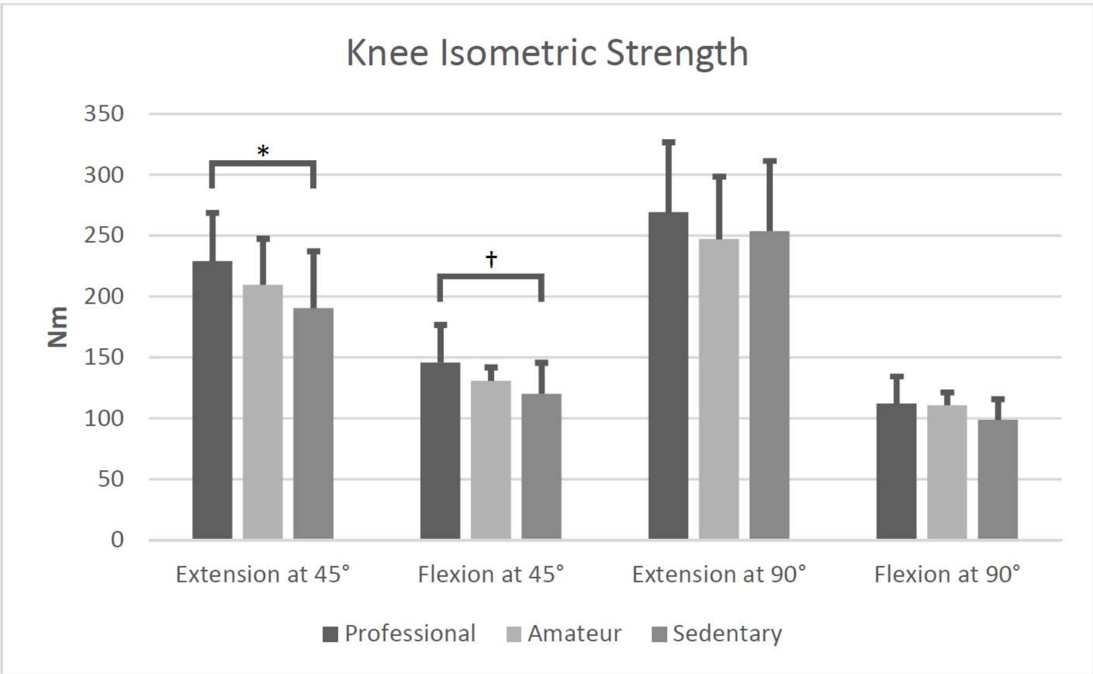

Figure 5. Knee isometric strength (Nm). Data are means ± SD's and represent absolute extension and flexion knee muscle isometric strength expressed in Nm of professional and amateur soccer players and sedentary persons.

[a] *, p<0.05. †, p<0.01

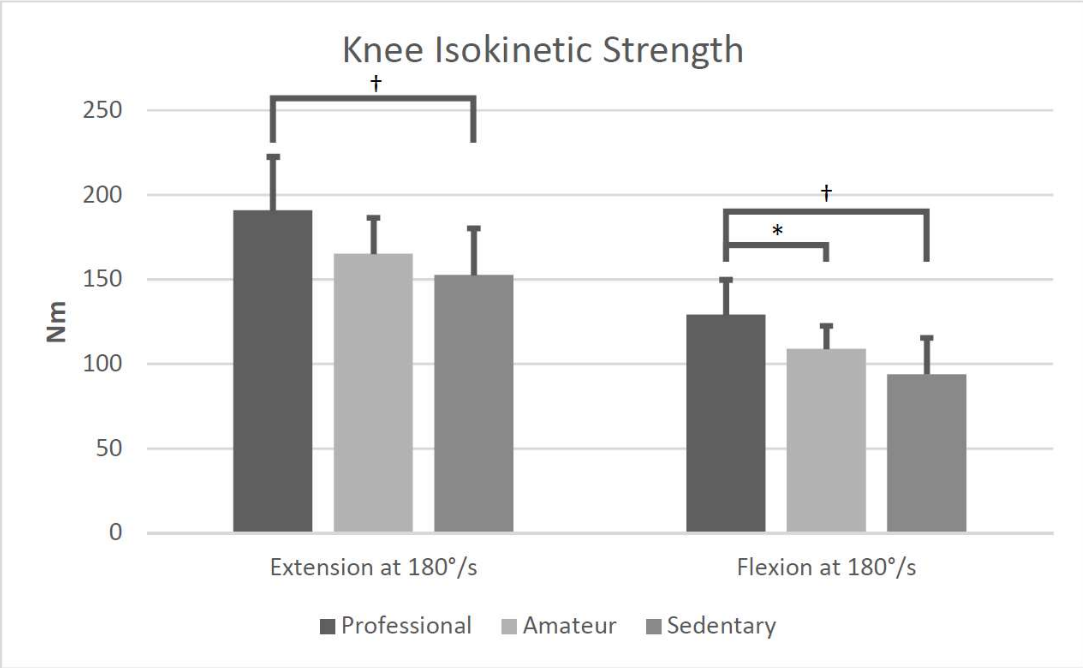

Figure 6. Knee isokinetic strength (Nm). Data are means ± SD's and represent absolute extension and flexion knee isokinetic muscle strength expressed in Nm of professional and amateur soccer players and sedentary persons.

[a] *, p<0.05. †, p<0.01

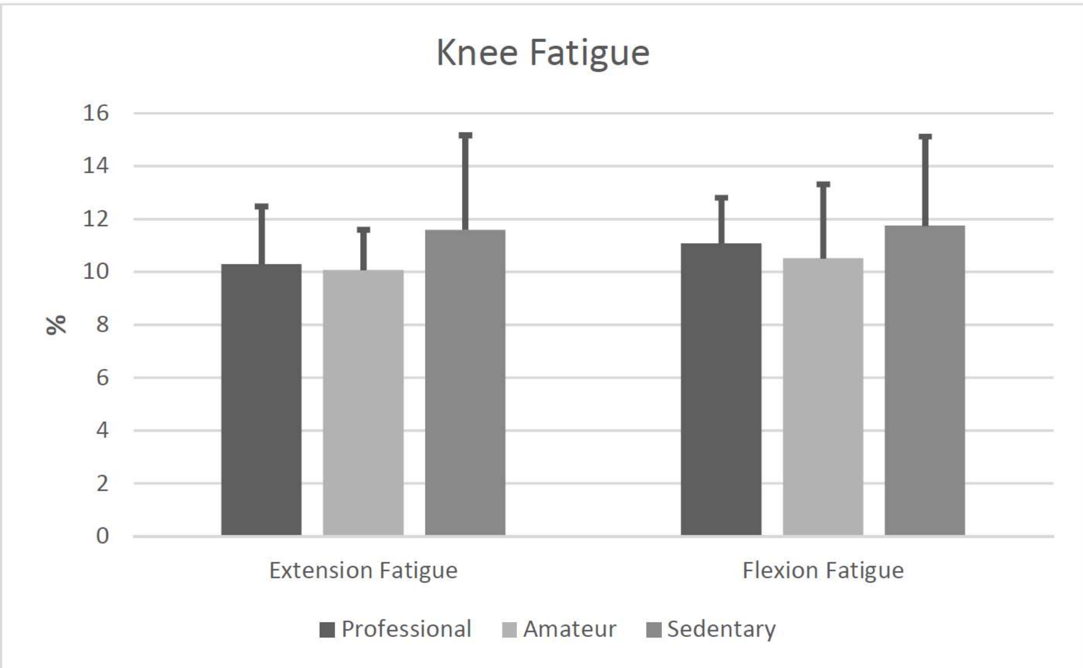

Figure 7: Knee fatigue (%). Data are means ± SD's and represent the percentage of fatigue in knee isokinetic flexion and extension of professional and amateur soccer players and sedentary persons.

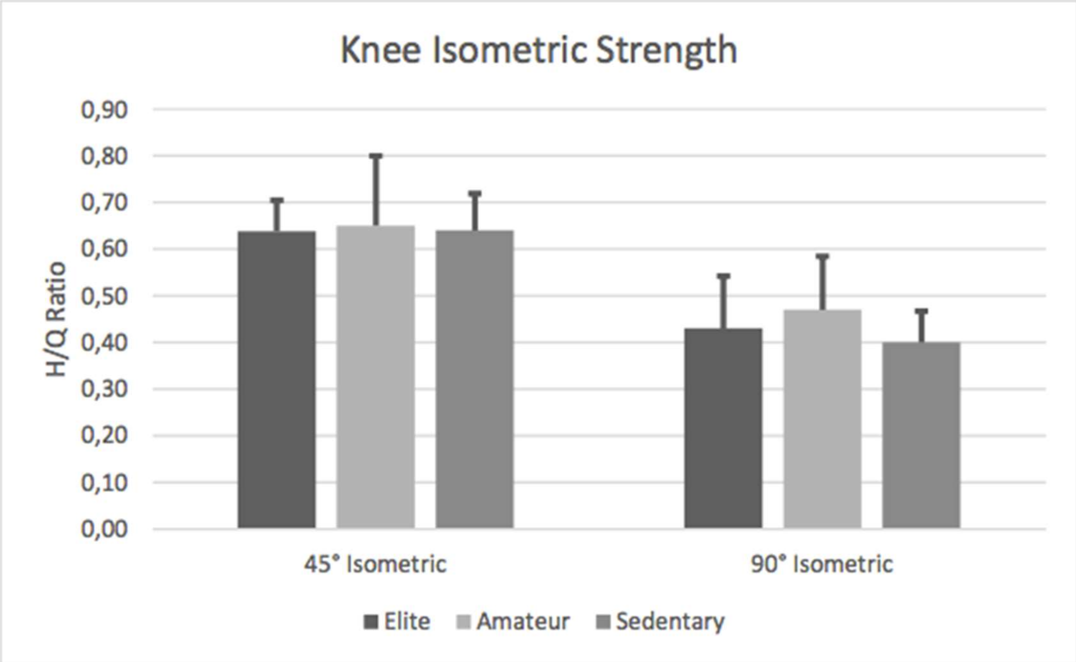

Figure 8. H/Q ratio in isometric measurements at 45° and 90°. Data are means ± SD's and represent the hamstring quadriceps ratio of isometric muscle strength at 45° and 90° of professional and amateur soccer players and sedentary persons.

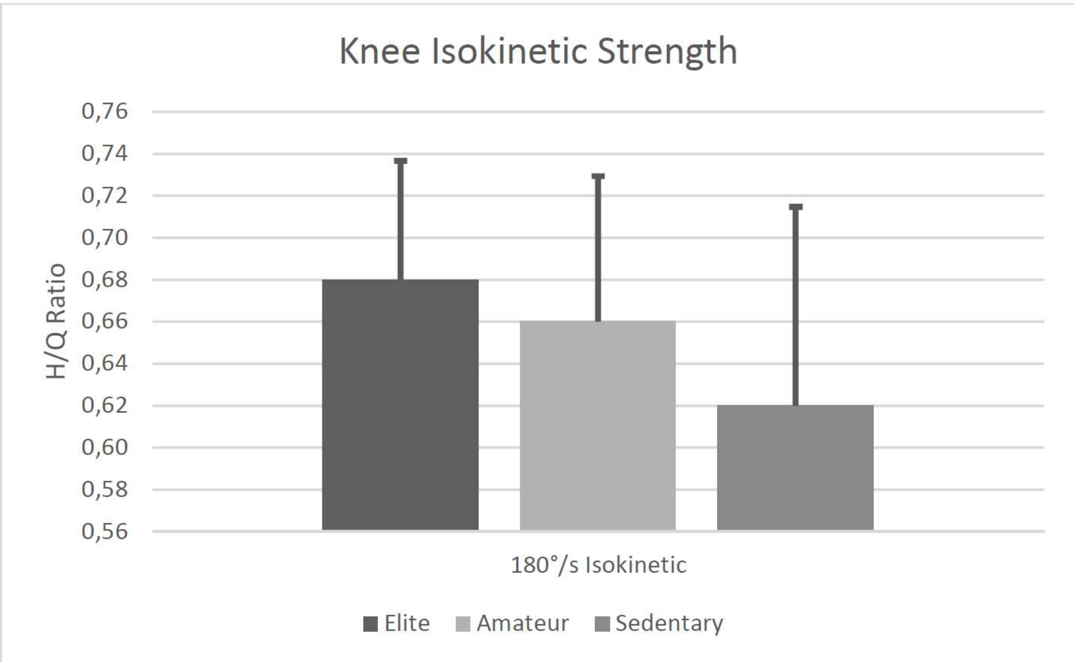

Figure 9. H/Q ratio in isokinetic strength measurements at 180°/s. Data are means ± SD's and represent hamstring quadriceps ratio of isometric knee muscle strength of professional and amateur soccer players and sedentary persons.

6.2 Secondary outcome measures

6.2.1 Trunk flexion-extension

6.2.1.1 Relative to total body weight (TBW)

In the semi-standing position, trunk extension strength relative to TBW of elite soccer players (4.55 ± 0.68 Nm/kg) was 22.0% higher compared to amateur soccer players (3.73 ± 0.67 Nm/kg) (p=0.009) and 19.1% higher compared to sedentary controls (3.82 ± 0.76 Nm/kg) (p=0.008). Moreover, in the semi-standing position, trunk flexion strength relative to TBW of elite soccer players (2.73 ± 0.24 Nm/kg) was 14.2% higher compared to sedentary controls (2.39 ± 0.45 Nm/kg) (p=0.013). In the lumbar position, trunk flexion strength relative to TBW of elite soccer players (2.72 ± 0.27 Nm/kg) was 17.7% higher compared to sedentary controls (2.31 ± 0.42 Nm/kg) (p=0.001). (Figure 10)

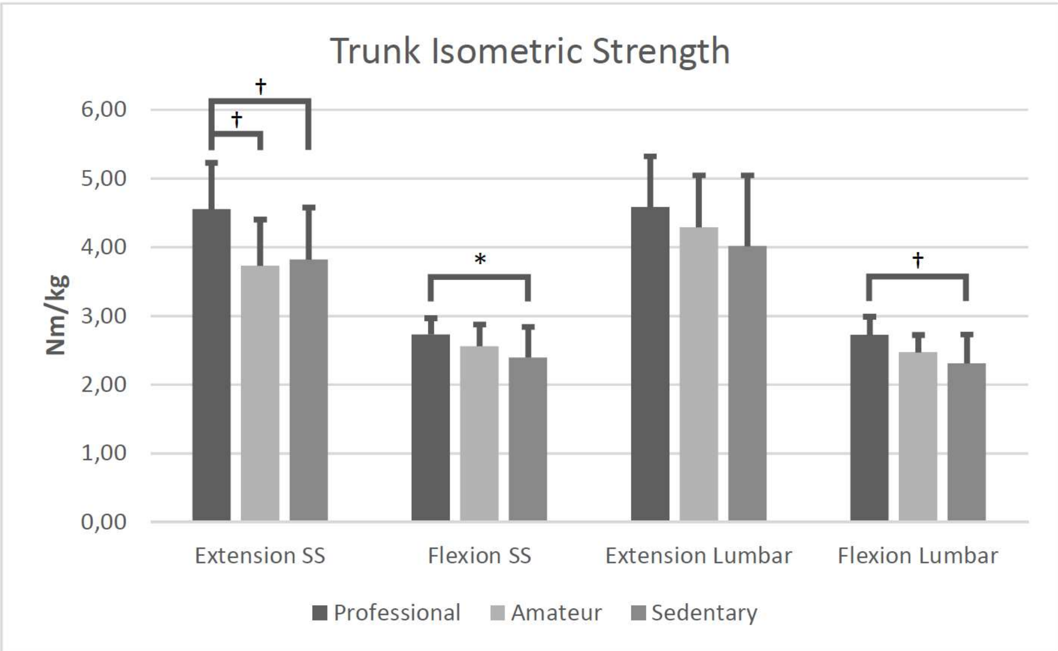

Figure 10. Trunk isometric strength relative to total body weight (TBW)(Nm/kg). Data are means ± SD's and represent extension and flexion of isometric trunk muscle strength relative to total body weight expressed in Nm/kg of professional and amateur soccer players and sedentary persons.

[a] *, p<0.05. †, p<0.01

6.2.1.2 Relative to total fat free mass (FFM)

In the semi-standing position trunk extension strength relative to FFM of elite soccer players (5.46 ± 0.80 Nm/kg) was 18.4% higher compared to amateur soccer players (4.61 ± 0.77 Nm/kg) (p=0.037). (Figure 11)

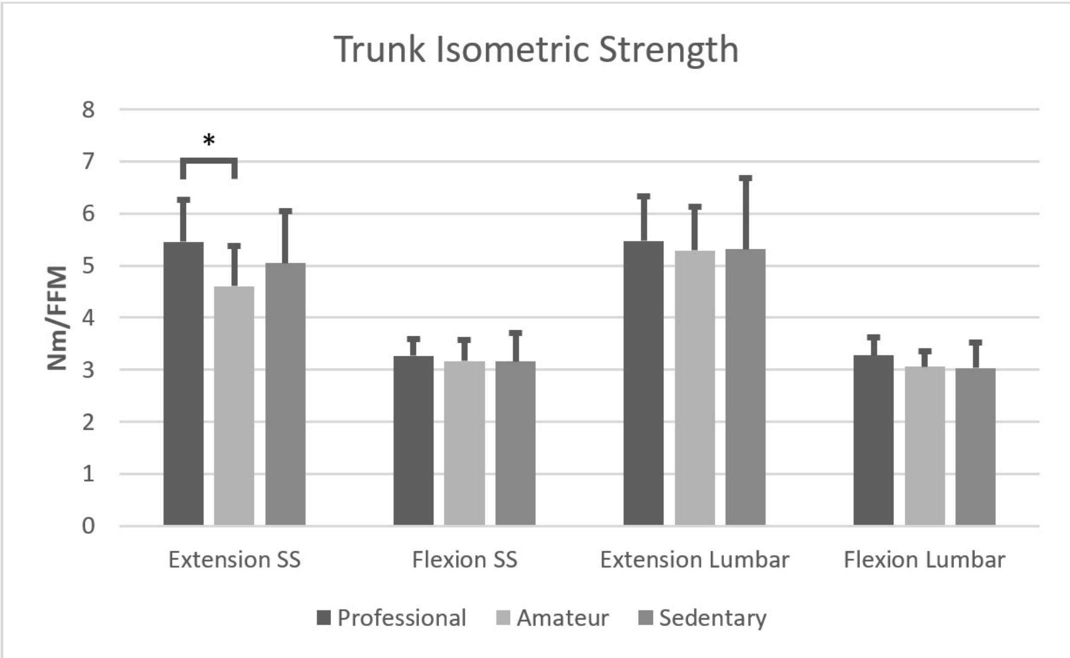

Figure 11. Trunk isometric strength relative to total fat free mass (Nm/FFM). Data are means ± SD's and represent extension and flexion of isometric trunk muscle strength relative to fat free mass expressed in Nm/kg of professional and amateur soccer players and sedentary persons.

[a] *, p<0.05.

6.2.1.3 Relative to FFM of the trunk

In the semi-standing position trunk extension strength relative to FFM of the trunk of elite soccer players (11.03 ± 1.64 Nm/kg) was 19.9% higher compared to amateur soccer players (9.20 ± 1.50 Nm/kg) (p=0.025). (Figure 12)

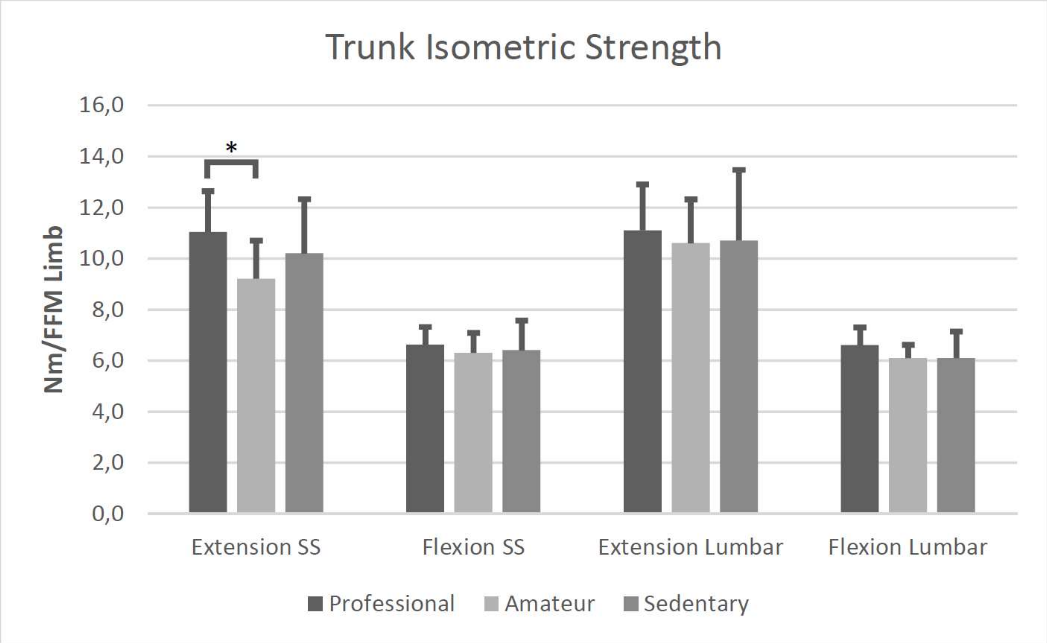

Figure 12. Trunk isometric strength relative to fat free mass of the trunk (Nm/FFM limb). Data are means ± SD's and represent extension and flexion trunk isometric muscle strength relative to fat free mass of the trunk expressed in Nm of professional and amateur soccer players and sedentary persons.

[a] *, $p<0.05$.

6.2.2 Hip abduction-adduction

6.2.2.1 Relative to TBW

No significant differences were found between the groups for hip abduction and adduction strength relative to body weight. (Figure 13)

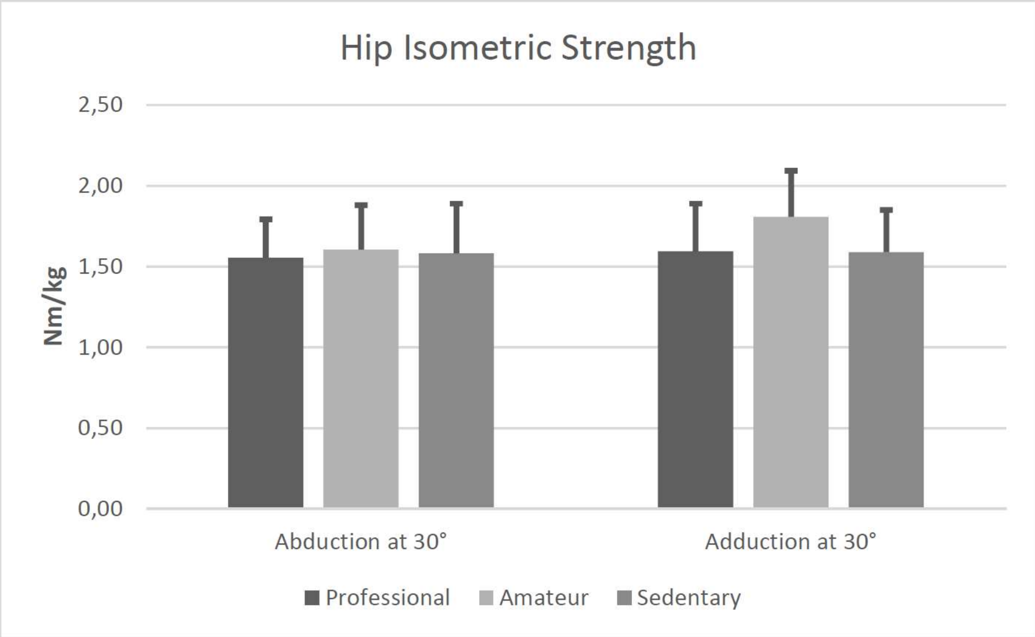

Figure 13. Hip Isometric Strength (Nm/kg). Data are means ± SD's and represent hip abduction and adduction isometric muscle strength relative to total body weight expressed in Nm/kg of professional and amateur soccer players and sedentary persons.

6.2.2.2 Relative to total FFM

No significant differences were found between the groups for hip abduction and adduction strength relative to fat free mass. (Figure 14)

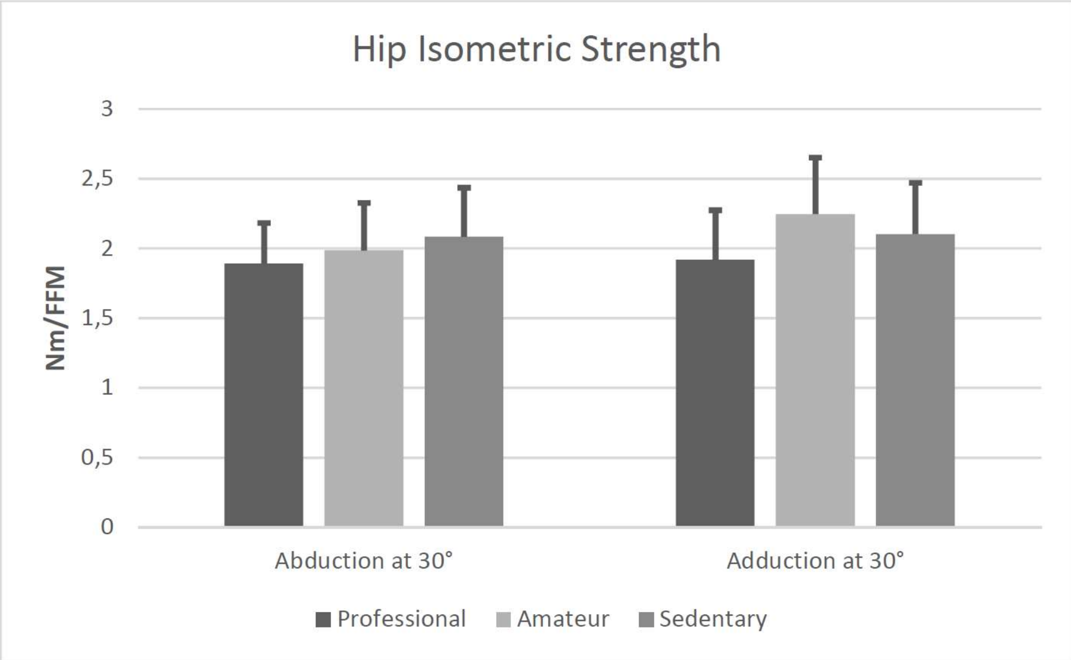

Figure 14. Hip Isometric Strength (Nm/FFM). Data are means ± SD's and represent hip isometric abduction and adduction muscle strength relative to fat free mass expressed in Nm/kg of professional and amateur soccer players and sedentary persons.

6.2.1.3 Relative to FFM of the leg

Isometric hip abduction strength relative to FFM of the leg of elite soccer players (11.19 ± 1.82 Nm/kg) was 17.2% lower compared to sedentary controls (13.12 ± 2.01 Nm/kg) (p=0.011). Isometric hip adduction strength relative to FFM of the leg of elite soccer players (11.48 ± 2.24 Nm/kg) was 20.3% lower compared to amateur soccer players (13.81 ± 2.62 Nm/kg) (p=0.030). (Figure 15)

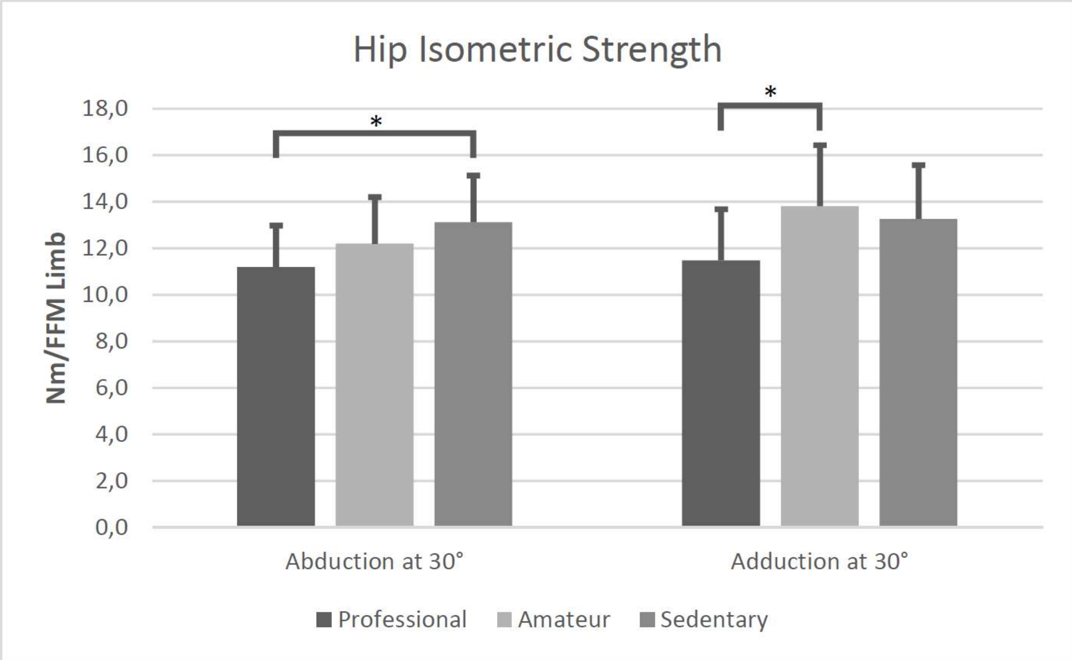

Figure 15. Hip Isometric Strength (Nm/FFM limb). Data are means ± SD's and represent hip abduction and adduction isometric muscle strength relative to fat free mass of the hip expressed in Nm of professional and amateur soccer players and sedentary persons.

[a] *, p<0.05.

6.2.3 Knee flexion-extension

6.2.3.1 Relative to TBW

Isometric knee extension strength of elite soccer players relative to TBW (3.02 ± 0.34 Nm/kg) was 17.5% higher compared to sedentary controls (2.57 ± 0.49 Nm/kg) in 45° (p=0.012). Isometric knee flexion strength of elite soccer players relative to TBW (1.49 ± 0.28 Nm/kg) was 11.2% higher compared to sedentary controls (1.34 ± 0.17 Nm/kg) in 45° (p=0.006).

Isokinetic knee extension and flexion strength of elite soccer players relative to TBW (2.52 ± 0.26 Nm/kg and 1.70 ± 0.17 Nm/kg) were 12,5% (p=0.04) and 14,9% higher (p=0.03) compared to amateur soccer players (2,24 ± 0,31 Nm/kg and 1.48 ± 0.23), respectively. Furthermore, isokinetic knee extension and flexion strength of elite soccer players relative to TBW (2.52 ± 0.26 Nm/kg and 1.70 ± 0.17 Nm/kg) were 21.7% (p<0.0001) and 32.8% higher (p<0.0001) compared to sedentary controls (2.07 ± 0.30 Nm/kg and 1.28 ± 0.27), respectively. (Figure 16-17)

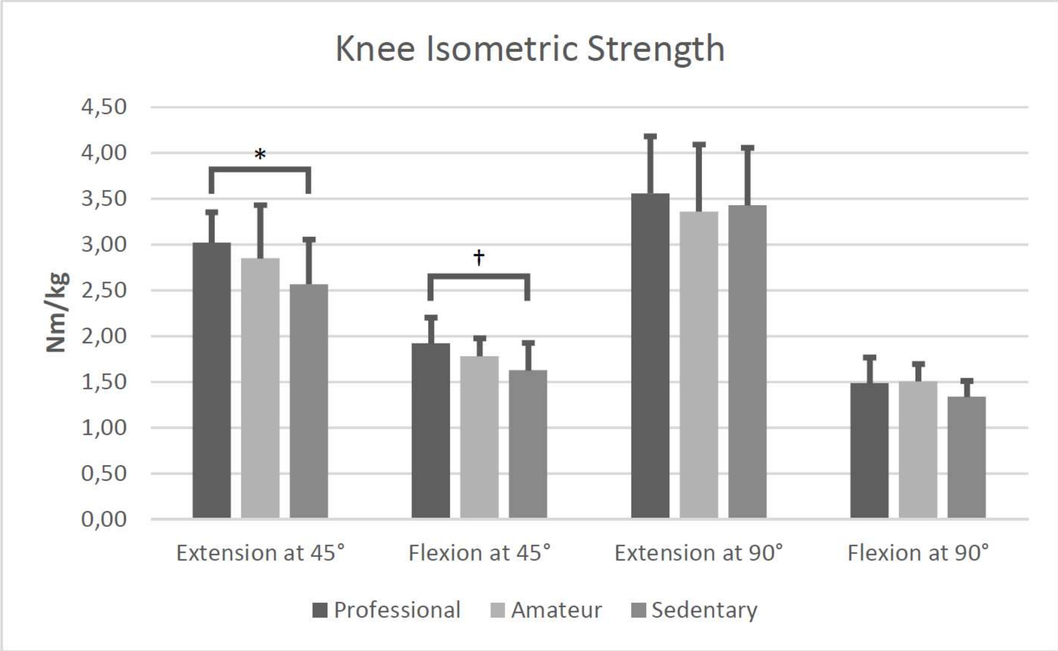

Figure 16. Knee Isometric Strength (Nm/kg). Data are means ± SD's and represent knee extension and flexion isometric muscle strength relative to total body weight expressed in Nm/kg of professional and amateur soccer players and sedentary persons.

[a] *, p<0.05. †, p<0.01

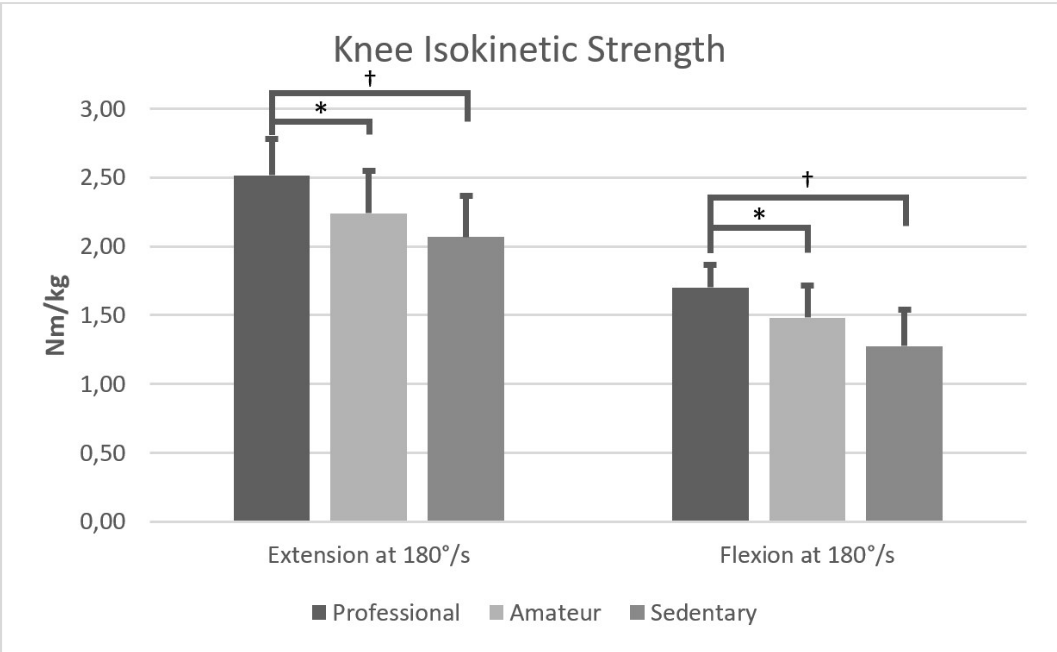

Figure 17. Knee Isokinetic Strength (Nm/kg). Data are means ± SD's and represent knee isokinetic muscle strength relative to total body weight expressed in Nm/kg of professional and amateur soccer players and sedentary persons.

[a] *, p<0.05. †, p<0.01

6.2.3.2 Relative to total FFM

Isokinetic extension (3.05 ± 0.33 Nm/FFM) and flexion strength (2.05 ± 0.20 Nm/FFM) relative to FFM of elite soccer players compared to sedentary controls were 12.1% higher for extension (2.72 ± 0.31 Nm/FFM) (p=0.04) and 22.0% higher for flexion (1.68 ± 0.30 Nm/FFM) (p=0.0004). (Figure 18-19)

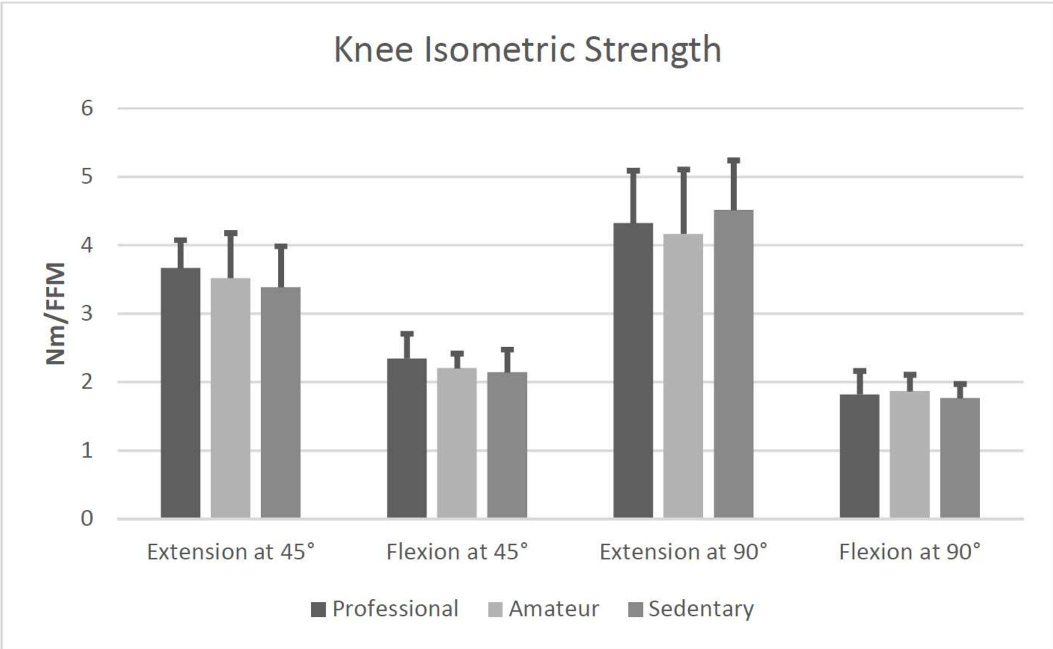

Figure 18. Knee Isometric Strength (Nm/FFM). Data are means ± SD's and represent knee extension and flexion isometric muscle strength relative to fat free mass expressed in Nm/kg of professional and amateur soccer players and sedentary persons.

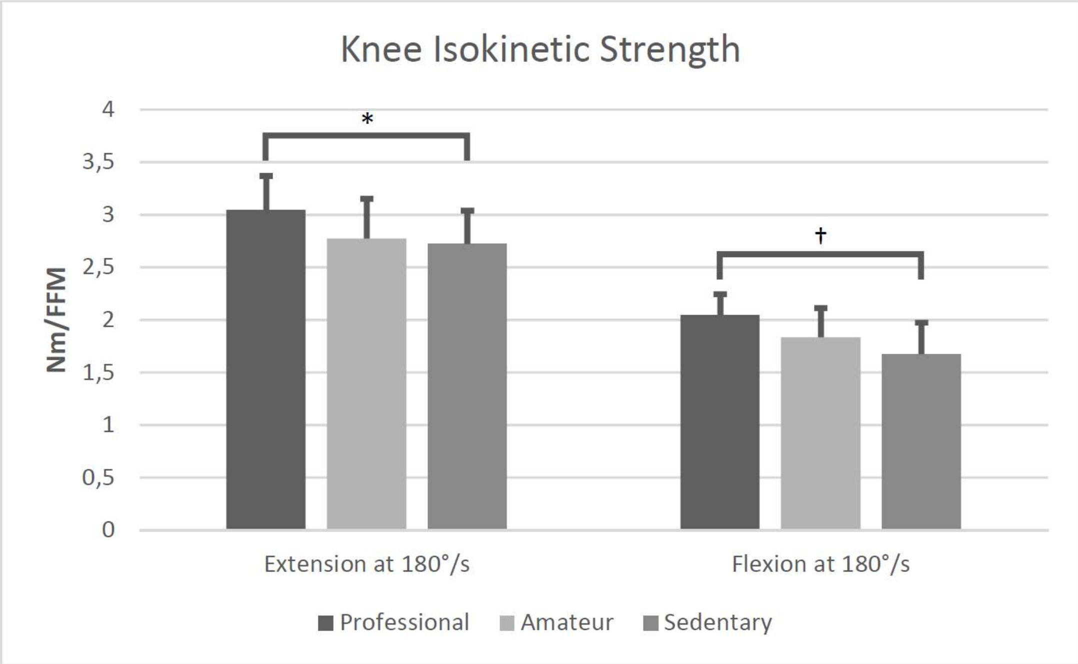

Figure 19. Knee Isokinetic Strength (Nm/FFM). Data are means ± SD's and represent knee isokinetic extension and flexion muscle strength relative to fat free mass expressed in Nm/kg of professional and amateur soccer players and sedentary persons.

[a] *, $p<0.05$. †, $p<0.01$

<u>*6.2.3.3 Relative to FFM of the leg*</u>

Isokinetic knee flexion strength relative to FFM of the leg of elite soccer players (12.23 ± 1.21 Nm/FFM) was 15.7% higher compared to sedentary controls (10.57 ± 1.80 Nm/FFM) (p=0.007). (Figure 20-21)

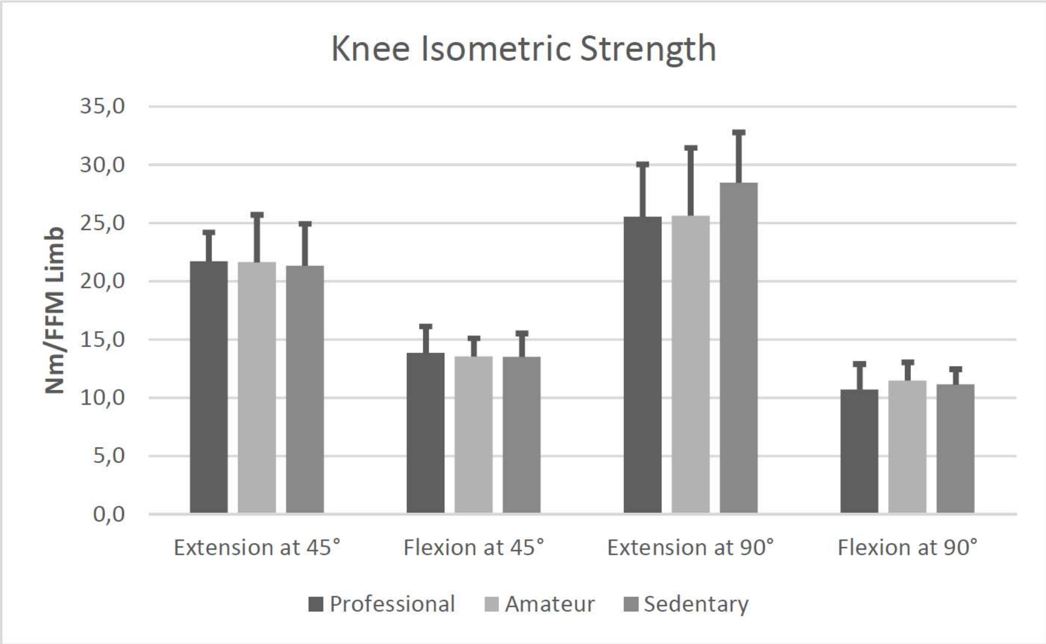

Figure 20. Knee Isometric Strength (Nm/FFM limb). Data are means ± SD's and represent knee extension and flexion isometric muscle strength relative to fat free mass of the leg expressed in Nm/kg of professional and amateur soccer players and sedentary persons.

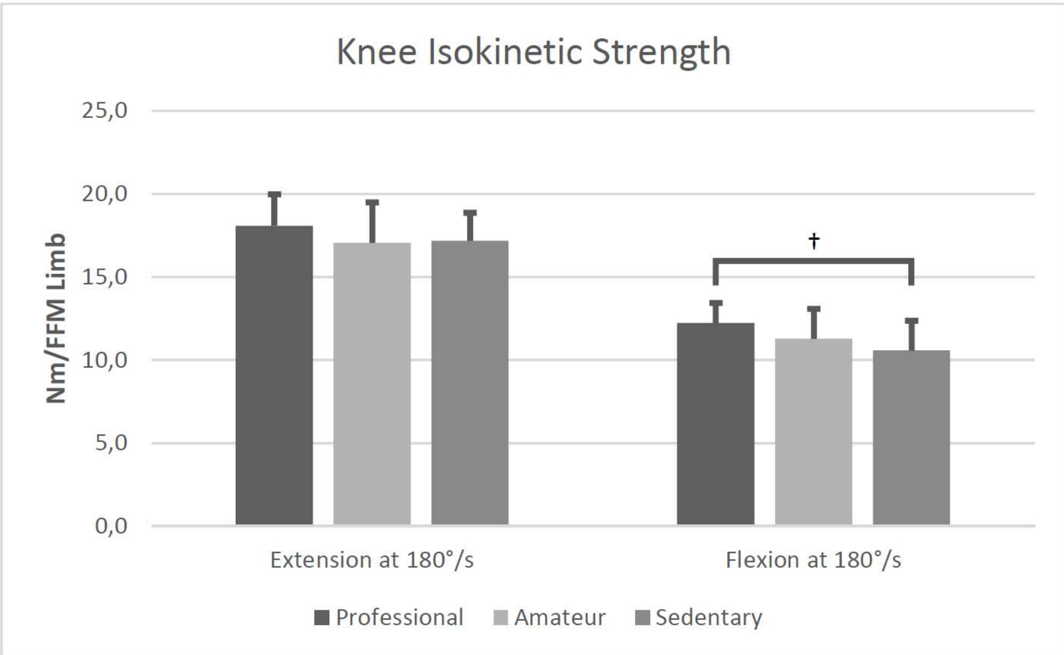

Figure 21. Knee Isokinetic Strength (Nm/FFM limb). Data are means ± SD's and represent knee extension and flexion isokinetic muscle strength relative to fat free mass of the leg expressed in Nm/kg of professional and amateur soccer players and sedentary persons.

[a] †, p<0.01

6.2.4 Demographics

There were no significant differences for age, body weight and BMI between groups. Regarding fat mass percentage there was a significant difference of 30,2% between the elite (7.6% ± 1.8) and amateur group (9.9% ± 2.9) ($p=0.0185$) and a difference of 84,2% between the elite and sedentary group (14% ± 5.1) ($p<0.0001$) in favor of the elite group. Furthermore, amateur soccer players had 41,4% lower fat mass percentage compared to sedentary controls ($p=0.0406$).

There were significant differences regarding total fat free mass (12,7% difference) (62.9 ± 5.6 kg vs. 55.8 ± 6.5 kg; $p=0.0015$), fat free mass of the legs (19,3% difference) (10.5 ± 1.1 kg vs. 8.8 ± 1.1 kg; $p<0.0001$) and fat free mass of the trunk (12,3% difference) (31.1 ± 2.7 kg vs. 27.7 ± 3.5 kg; $p=0.003$) between the elite and sedentary group in favor of the elite group.

7. DISCUSSION

To our knowledge, this study is the first to investigate and compare muscle strength relative to fat free mass of the measured limb of soccer players of different divisions and sedentary controls. We can conclude that elite soccer players have higher strength values for trunk extension in the semi-standing position (vs. amateur soccer players) and isokinetic knee flexion (vs. sedentary controls) for all relative strength measurements. Elite players also show higher strength values for some of the measured muscle groups, but not for all of them in comparison with other study groups. Moreover, amateur soccer players show higher strength values for several muscle groups compared to sedentary controls. Regarding hip strength, elite soccer players achieved lower strength values for hip abduction when compared to sedentary controls and hip adduction when compared to amateur soccer players. The findings are consistent compared to the results of Thorborg, Couppé, Petersen, Magnusson, and Hölmich (2011) who found higher adduction values in a recreational group compared to elite soccer players. The opposite was found for abduction. Peak torques of adduction were higher than abduction resulting in an adductor/abductor ratio above 1. This is consistent with Masuda, Kikuhara, Demura, Katsuta, and Yamanaka (2005) and Masuda, Kikuhara, Takahashi, and Yamanaka (2003) who found an adductor/abductor peak torque > 1 in sub elite soccer players during maximal isokinetic muscle strength tests. Thorborg et al. (2011) also found this with isometric hip muscle strength. The contrasting results of this study can be explained due to the deviant measurement position that will be discussed as a limitation of the study protocol. Ranging from the least specific outcome measure, being absolute strength, to the most specific outcome measure, being relative strength (normalized by FFM of the measured limb), less differences between muscle groups were identified between elite soccer players, amateur soccer players and sedentary controls. No differences in relative strength for FFM of the measured limb between the three groups prove that elite soccer players are unable to generate strength more efficiently compared to amateur soccer players (except for extension in the semi-standing position) and sedentary controls (except for isokinetic flexion). This demonstrates the importance of using relative strength values. Using absolute strength values to compare the three groups will give a distorted interpretation of the results because of lower fat mass and higher fat free mass of elite soccer players in comparison with amateur soccer players and sedentary controls.

Relative strength is widely expressed relative to total body weight (TBW). Nowadays, there is only little evidence concerning strength relative to fat free mass (FFM) in soccer. Portella et al (2014) is, to our knowledge, the only study that showed maximal strength values relative to FFM in soccer. Their results showed a higher concentric extensor torque than flexor torque. They also found significant differences between the dominant and non-dominant leg. To date, not one study expressed strength relative to FFM of the measured limb in soccer. This method has the ability to determine if trained individuals (athletes) can generate more strength relative to muscle mass in comparison with less trained individuals and sedentary people.

7.1 Strengths and limitations

All measurements were performed in a professional setting according to a standardised measurement protocol using the BIODEX® dynamometer to assess maximal strength and DEXA scan to assess body composition. Both devices are considered as 'golden standards' and represent a strength of these study. All maximal strength tests are performed by low experienced assessors, which could be a possible limitation of the study. Consequently, varied instructions and a varied protocol can lead to deviating results between assessors. To exclude this bias, each test was performed by 2 assessors at the same time, guided throughout all measurements by an experienced assessor. A second weakness is the measurement position of maximal hip abduction and adduction strength. The standing position did not allow to control compensated movements of the lower and upper body. This could influence maximal hip abduction and adduction strength and gave biased results. A more fixed position (e.g. side lying position) is recommended to assess maximal hip abduction and adduction strength using the BIODEX® dynamometer. Finally, it is important to note that it is impossible to determine if all participants achieved their maximal strength during the strength measurements. To cope with this, all participants were verbal encouraged to reach their maximal strength.

7.2 Recommendations for future research

Since this is the first study that compared strength relative to FFM of the measured limb between different division soccer players and sedentary controls, more research with a higher number of participants is recommended to support or refute these findings. As stated in the limitations, a more standardised position to measure maximal hip abduction and -

adduction strength, such as side lying, is recommended to assess maximal hip strength using a BIODEX® dynamometer. Also, it might be more correct if hip strength was normalized using the FFM of the trunk instead of the legs, since a lot of the force is being generated in the core muscles.

7.3 Conclusion

Because there clearly is a difference in body composition between elite soccer players, amateur soccer players and sedentary controls, it is important to compare relative strength values between these groups. Therefore, this study uses, besides the common way to normalise these values (which is by using bodyweight), a method to express relative strength by using the FFM of the measured limb. This provides the ability to assess if more strength can be generated with the same amount of muscle over different populations, thus determining the efficiency. It can be concluded that elite soccer players can only generate strength more efficiently for extension of the trunk in the semi-standing position when compared to amateur soccer players and for isokinetic flexion when compared to sedentary controls.

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03/10/2017	Plannen van metingen + overlopen MP2	Promotor: BERT OP 'T EIJNDE UNIVERSITEIT HASSELT Biomed - Reval Agoralaan gebouw A 3590 DIEPENBEEK Copromotor: Student(e): Student(e):
20/02/2018	Bespreking grafieken + interpretatie en bespreking structuur MP2	Promotor: BERT OP 'T EIJNDE UNIVERSITEIT HASSELT Biomed - Reval Agoralaan gebouw A 3590 DIEPENBEEK Copromotor: Student(e): Student(e):
28/05/2018	Niet-bindend advies	Promotor: BERT OP 'T EIJNDE UNIVERSITEIT HASSELT Biomed - Reval Agoralaan gebouw A 3590 DIEPENBEEK Copromotor: Student(e): Student(e):
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Ik/wij verlenen het wereldwijde auteursrecht voor de ingediende eindverhandeling:
Trunk and Lower Body Muscle Strength in Soccer

Richting: **master in de revalidatiewetenschappen en de kinesitherapie-revalidatiewetenschappen en kinesitherapie bij musculoskeletale aandoeningen**
Jaar: **2018**

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Voor akkoord,

Max, Mathias **Vanstiphout, Luca**

Datum: **4/06/2018**