NORWEGIAN SCHOOL OF SPORT SCIENCES

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The relationship between training load and physical fitness development among football players during adolescence

A longitudinal study

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Abstract

Objectives: Given the importance of physical fitness for football players, it is of interest to further increase this aspect. Additionally, the level of physical fitness increases during adolescence. This study intends to get a better understanding of the relationship between training load measures and development in physical fitness during adolescence.

Method: Boys (14.4 ± 1.6 years, n=16) and girls (14.4 ± 0.9 years, n=12) completed pre- and post-testing separated by one year. In-between testing, training load measures were collected for three two-weeks periods. Physical fitness was assessed by performing; 10-m and 30-m sprint, change of direction, countermovement jump, Keiser leg press, and YoYo intermittent recovery test 1. Training load measures were collected using global navigation satellite system units, additionally to self-reported session rate of perceived exertion. Correlation analyses were performed between average training load measures per period and percentage change in physical fitness characteristics.

Results: Boys performed better compared to girls in six physical fitness tests during pre-testing, and eight tests during post-testing. Girls performed better in four tests, whereas boys performed better in all nine tests during post-testing compared to pre-testing. Boys had greater percentage change in total force (31.4% vs. 14.0%) and total power (36.6% vs. 13.5%) in leg press compared to girls. Many training load measures were similar between sexes, but boys covered more distance sprinting (947 ± 620m vs. 468 ± 266m), had more efforts of sprinting (68 ± 42 vs. 36 ± 9) and had more high-intensity efforts (HIE) (543 ± 252 vs. 270 ± 113). A total of twenty-four correlations between training load measures and change in physical fitness tests were significant. No correlations were significantly for both sexes. The strongest correlation for boys was between change in relative force and efforts of high relative sprinting (r=0.66), whereas the strongest correlation for girls was between change in relative force and efforts of sprinting (r=0.79).

Conclusion: Boys had a higher level of physical fitness and were also the ones to develop their level of physical fitness the most throughout one year. Boys had higher training load measures of sprinting and HIE. Several training load measures correlated with change in physical fitness, indicating a relationship between these measures. Here, higher training load measures were associated with a greater change in physical fitness.

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Forord

Først og fremst vil jeg starte med å takke alle de fantastiske menneskene jeg har møtt på Norges Idrettshøgskole igjennom fem innholdsrike år. Alle medstudenter, forelesere, ansatte og vaskepersonale har vært med på å gjøre disse årene såpass innholdsrike.

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Tor-Magnus Blakstad Cappelen

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1. Introduction

As a result of the increasing physical demands for the elite players, youth players also need to adapt to a higher level of physical performance (Barnes et al., 2014, p. 1096). Match performance, measured in external load, has been linked to the level of physical fitness of youth football players (Buchheit et al., 2010, p. 822). Therefore, to further increase performance during matches, it is of interest to further increase the level of physical fitness. However, as the level of physical fitness is expected to increase throughout adolescence, the additional effect of training load, particularly in relation to measures of training load, is more unclear (Buchheit et al., 2010, p. 819; Greier et al., 2019, p. 262).

Training interventions have shown that athletes during adolescence will adapt to training interventions and improve physical fitness in abilities such as speed, agility, jumping, strength, and endurance (Buchheit et al., 2010, p. 2717; Baxter-Jones & Maffulli, 2003, p. 96; 2010, p. 2717; Hammami et al., 2017, p. 5; Lesinski et al., 2020, p. 1927). Furthermore, a regime with higher training volume has been proven to increase these physical abilities, relevant for football players, more compared to a regime with lower training volume (Hammami et al., 2013, p. 594; Wrigley et al., 2014, p. 1092). With the increased use of global navigation satellite systems (GNSS) to track external training load measures (Malone et al., 2017, p. 19), and the use of session rate of perceived exertion training load (sRPE-TL) (Foster et al., 2001, p. 113; Impellizzeri et al., 2004, p. 1043) to track internal training load, it would be of interest to further investigate if there are any of these measures that has a relationship with the development in physical fitness characteristics during adolescence.

1.1 Purpose of the Study

This study has been performed to get a better understanding of the relationship between training load measures and development in physical fitness during adolescence for football players. With increased knowledge of this relationship, training load can be manipulated to better improve physical fitness and therefore enhance performance during matches. Here, football players of both sexes were monitored throughout one year to track training load, additionally to track their development in physical fitness characteristics.

1.2 Research Questions

The main research question for this study was: "What is the relationship between training load measures and development in physical fitness for football players during adolescence". In additionally to the main research question, this study will also further investigate:

- If there are differences in physical fitness between sexes of the same age during adolescence?
- If there are differences in development in physical fitness between sexes of the same age during adolescence
- If there are differences in training load measures between sexes of the same age during adolescence?

2. Theoretical Background

For the theoretical part of this thesis, different aspects related to the study will be presented. Firstly, the physical demands related to football will be presented as this thesis focuses on the physical fitness of youth football. Secondly, information about growth and maturation, along with development during adolescence is presented to inform about changes occurring during adolescence without training regimes. Thirdly, two different ways to track and register training load will be introduced as this is relevant to better understand training load measures, additionally, to better understand the methods used to collect data throughout this study. Lastly, development related to different training regimes during adolescence will be presented to better understand relevant physical fitness characteristics, and what level of development to expect from this study. The theoretical background will, additionally to give a better understanding the method- and result chapter, also be used when discussing the results from this study.

2.1 Physical Demands in Football

The game of football enjoys global recognition, and its immense popularity is reflected in the substantial number of individuals who participate in it. Football is a multifaceted sport, as it demands a diverse range of skills both during training and in competitive matches (Carling, 2013, p. 656). Therefore, to perform at a highly competitive level, the player needs to master several skills simultaneously (Carling, 2013, p. 656). Despite this thesis focusing on the physical demands, the player also needs to master technical, tactical, and psychological abilities (Carling, 2013, p. 656). As the physical demands have increased throughout the last decade, this alters the level of competition which the player needs to adapt to (Andersen et al., 2004, p. 626; Barnes et al., 2014, p. 1096). Barnes et al. (2014, p. 1097) found that the average distance covered during matches in the English Premier League from the 2006-07 season to the 2012-13 season increased by 1.9%. Despite being statistically significant ($p<0.01$), the change was only trivial (Barnes et al., 2014, p. 1096). However, they also compared high-speed running distance (HSR) (19.8-25.1km/h) and sprinting (>25.1km/h) distance for the same period and found greater changes favoring the newer seasons (Barnes et al., 2014, p. 1097). HSR distance increased by 29% from the 2006-07 season, not even being the season with the lowest numbers, to the last season 2012-13 (Barnes et al., 2014, p. 1096). The increase is reflected by the increase of HSR distance actions which increased by 49% per match. Similar increases were seen in the distance covered by sprinting and the number of sprints, 51% and 84%, respectively (Barnes et al., 2014, p. 1096).

The reason for discussing these measures, HSR and sprinting, is that it seems like with an increase in competitive level, the distance covered and the number of actions for these measures increases (Mohr et al., 2003, p. 523). When Mohr et al. (2003, p. 523) compared moderate, Danish League, to top-class, both Italian-, and Champions League, players, the top-class players performed more HSR and sprint actions (Mohr et al., 2003, p. 523). Mohr et al. (2014, p. 523) observed that the average number of high-speed runs (>18km/h) during a match was close to 50 for moderate players, which constituted about 2% of the total time. In contrast, top-class players performed an average of close to 70 high-speed runs, making nearly 3% of the total time engaged in high-speed activity (Mohr et al., 2003, p. 523). Notably, the mean duration of high-speed runs did not vary between the level of players (Mohr et al., 2003, p. 523). Similar findings were found regarding sprinting where moderate players sprinted less (>30km/h) compared to top-class players (Mohr et al., 2003, p. 523). The top-class players performed 50% more sprints, resulting in 55% more time spent sprinting (Mohr et al., 2003, 523). Despite HSR and sprinting making such a small share of the total, it seems as if these actions are crucial in match-winning moments (Barnes et al., 2014, p. 1099; Stolen et al., 2005, p. 509). Similar results were obtained for youth players participating in an elite under-17 international cup, wherein the top and middle-ranked teams were found to cover a greater distance while sprinting compared to the bottom-ranked teams, with a respective increment of 8% and 6% in the distance covered (Varley et al., 2017, p. 23).

In contrast to Mohr et al (2003, p. 523), Di Salvo et al. (2009, p. 208) found that teams in the bottom, and the mid-table in the English Premier League covered a greater distance in several speed categories compared to the teams finishing at the top five. The top five teams covered on average 4% less HSR (>19.8km/h) per match, being statistically different from both the mid-table and the bottom-table teams (Di Salvo et al., 2009, p. 208). Similar findings apply to the distance covered by sprinting (>25.2km/h) (Di Salvo et al., 2009, p. 208). However, these differences could be explained by the different approaches to collecting data. Whereas Mohr et al. (2003, p. 523) compared two different leagues, Di Salvo et al. (2009, p. 208) compared several teams in the same league. A collection from Rampinini et al (2007, p. 1020) supports the findings that teams seem to decrease their distance covered in different speed categories as they play against teams of a lower level. This reflects the influence of the opponents, as it seems like the better teams can apply a different tactical approach as they have the advantage over the other team - especially when being in the lead (Di Salvo et al., 2009, p. 209). Despite the distance throughout the entire match might not be different, it is discussed if this might be a consequence as the better teams will have higher intensity in the first half, bringing them to the lead for them to later change the tactical approach (Di Salvo et al., 2009, p. 211; Rampinini et al., 2007, p. 1022).

Additional to the time spent, or distance covered in different speed thresholds, agility and speed are both important aspects of football (Bloomfield et al., 2007, p. 68). Agility is defined as "rapid whole-body movement with change of velocity or direction in response to a stimulus", whereas speed is defined as "the ability from the neuromuscular system to create horizontal acceleration" (Gjerset et al., 2015, p. 443; Sheppard & Young, 2006, p. 922). When Bloomfield et al. (2007, p. 68) analyzed the Premier League they discovered that players, depending on position, performed somewhere between 500-700 purposeful changes of directions (CoD). Also, Mohr et al. (2003, p. 522) estimated players to perform 150-250 intense actions throughout a match. With the complexity and the unpredictable aspect of the sport, the ability to rapidly change movement patterns in response to players and the ball is important in both the defending and attacking phases (Bloomfield et al., 2007, p. 69).

2.2 Growth, Maturation, and Development During Adolescence

Throughout adolescence, individuals experience a developmental transformation from a state of childhood to that of young adulthood. During childhood; physiological, anthropometrical, and motor control differences between boys and girls are relatively small (Armstrong & Mechelen, 2017, p. 49). The processes of growth and maturation are ongoing from the moment of birth until individuals are considered "fully grown up", nevertheless, the timing and pace of these changes are unique to each individual (Armstrong & Mechelen, 2017, p. 3).

2.2.1 Growth

Growth refers to the size or mass of either the whole individual or specific parts of the body (Armstrong & Mechelen, 2017, p. 3). The most commonly used measurements are height, sitting height (estimating lower body length) and weight, however, it is also possible to measure fat mass (FM), fat-free mass (FFM), and bone mineral content with different techniques and equipment (Armstrong & Mechelen, 2017, p. 3). As there are large differences for every individual, there are also differences in when boys and girls commonly reach their peak height velocity (PHV) (Malina & Koziel, 2014a, p. 426; 2014b, p. 1378). Furthermore, the average age at which boys experience their PHV is between thirteen and fifteen years of age, whereas the PHV appears earlier for girls, commonly between the age of eleven and thirteen years of age (Malina & Koziel, 2014a, p. 426; 2014b, p. 1378). The growth starts distal, at the hands and feet, before gradually moving proximal to the thigh and torso (Armstrong & Mechelen, 2017, p. 18). As shown in Figure 1, leg length grows at a higher velocity earlier compared to how the sitting height evolves, this is equal regardless of sex (Mirwald et al., 2002, p. 690). The peak increase in mass is delayed by one year compared to the PHV, where the majority of the mass is made up of fat for girls and muscles for boys (Corso, 2018, p. 152).

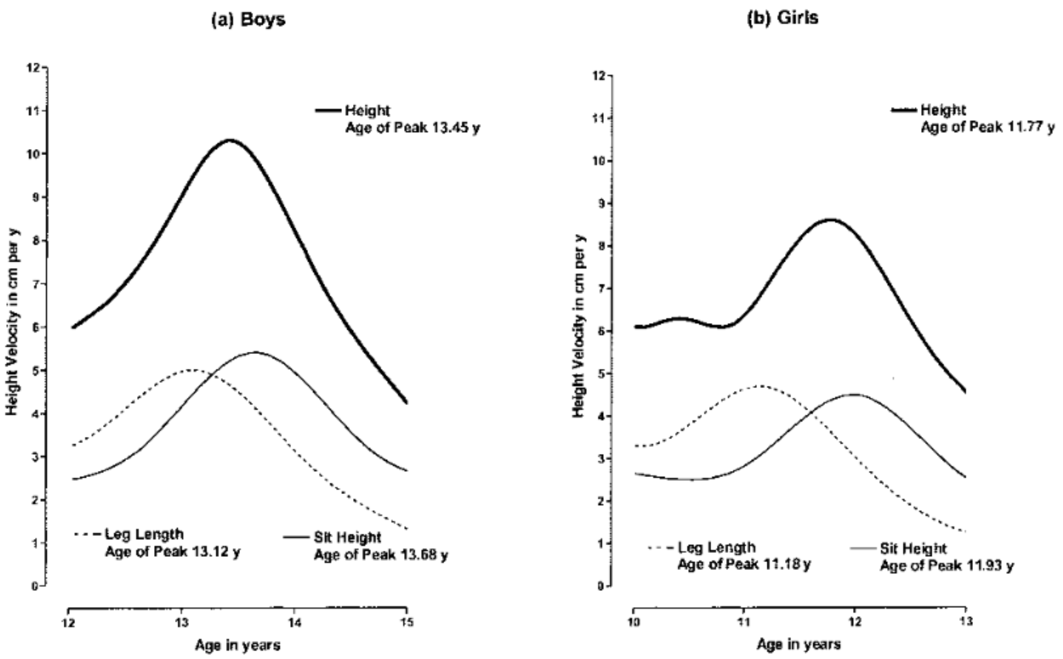


Figure 2.1: The figure is taken from "An assessment of maturity from anthropometric measurements" and is meant to illustrate the differences in growth between girls and boys, in additionally to differences in growth in leg length compared to sitting height (Mirwald et al., 2002, p. 690).

2.2.2 Maturation

Maturation is the process by which the body develops and matures, leading to physical changes and improvements in physical abilities (Armstrong & Mechelen, 2017, p. 4). Maturation is a key factor in physical development and performance for young athletes. Here, they experience changes in body composition, muscle mass, and bone density, which further will affect their strength, power, and endurance (Wrigley et al., 2014, p. 1092). The level of maturity can be estimated in many different ways, such as; skeletal-, dental-, hormonal- and somatic maturity (Beunen et al., 2006). One method used to determine the level of maturity is taking an x-ray of the wrist as this gives information about the skeletal age (Beunen et al., 2006, p. 245). Another method used is the ratio between standing and seated height as the lower limbs grow before the upper extremity (Beunen et al., 2006, p. 249). Similarly, as with growth, girls seem to mature earlier compared to boys, leading to earlier changes for girls (Malina & Koziel, 2014a, p. 426; 2014b, p. 1378).

2.2.3 Physical Fitness Development During Adolescence Without Training Stimuli

Growth will affect the biomechanics and therefore the coordinative capabilities during adolescence, factors like the center of gravity, often referred to as the center of mass, changes relatively rapidly (Corso, 2018, p. 153). Boys have a larger increase in shoulders width giving them an advantage in throwing sports as this increases the rotational forces. Whereas girls have a larger increase in the hip region, lowering the center of gravity and giving advantages in sports requiring balance (Armstrong & Mechelen, 2017, p. 18).

Maturation is associated with an increase in physical performance due to factors like increased growth and improved neuromuscular systems (Corso, 2018, p. 155; Greier et al., 2019, p. 262). For boys, the increase in physical performance is mainly caused by the increase in muscle mass and the increased concentration of hemoglobin as a result of the increase in growth hormone and testosterone (Rogol et al., 2003, p. 195). As chronological age and maturity level proceed independently this will affect performance during adolescence (Wrigley et al., 2014, p. 1092). Consequently, early-maturing athletes may be at an advantage, as adolescence is frequently considered a pivotal stage of life for selection into academies or teams with superior training regimes (Grendstad et al., 2020, p. 255). However, the beneficial sides of maturation might differ to some degree for girls.

Girls also seem to increase their strength during adolescence as they also get influenced by an increase in the steroid estrogen, however, simultaneously they have a larger increase in fat mass than boys, potentially negatively affecting their performance in sports (Armstrong, 2017, p. 92; Armstrong & Welsman, 2019, p. 205; Rogol et al., 2003, p. 195). Girls also seem to reach a plateau around the age of thirteen, rather than keep improving their physical fitness throughout adolescence as boys do (Greier et al., 2019, p. 262). As illustrated underneath by Greier et al. (2019, p. 262) in a cross-sectional study, boys kept improving with age when testing; sprinting and standing long jump. Similar findings were found for push-ups, sit-ups, and running (Greier et al., 2019, p. 262). These are the improvements found in a large sample of students, regardless of training, therefore it will be of interest to better understand if there is additional development with training.

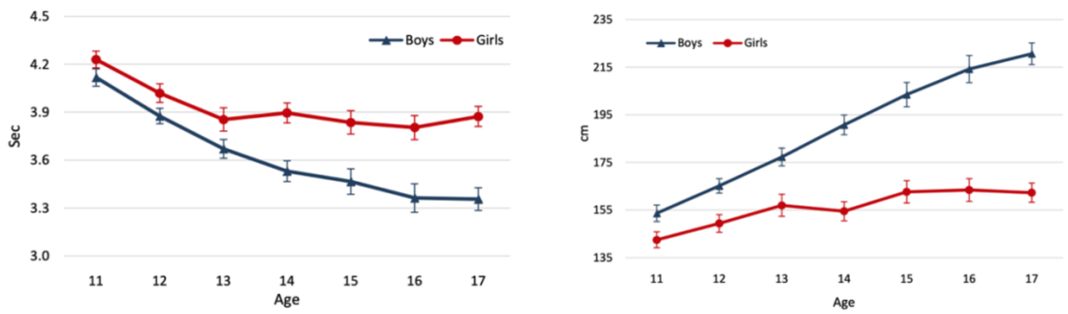


Figure 1. 20-m-Sprint performance by age and sex (N = 2267). Values are mean with 95% CI.

Figure 2. Standing long-jump performance by age and sex (N = 2267). Values are mean with 95% CI.

Figure 2.2: The figure is taken from "Physical Fitness across 11- to 17-Year-Old Adolescents: A Cross-Sectional Study in 2267 Austrian Middle- and High-School Students" showing the development in sprinting and standing long jump from the age of 11- to 17- years of age for both sexes (Greier et al., 2019, p. 262).

2.3 Training Load

Athletes are subjected to a training load to improve their physical abilities that are relevant to their sport, thereby enhancing their overall performance (Viru & Viru, 2000, p. 67). The stress infused by a single or series of exercises results in adaptations in different organisms (Viru & Viru, 2000, p. 67). The goal of structured training is to optimize the adaptations for a prolonged time. To achieve this, stress applied to the athletes needs to be manipulated on an individual level (Impellizzeri et al., 2019, p. 270). Monitoring of training load might therefore be a great tool for understanding the athlete's progression, or in the worst-case, regression (Bourdon et al., 2017, p. 161). Furthermore, load monitoring might also help optimize the training program by better understanding the individual's response to the training stimuli (Bourdon et al., 2017, p. 161).

Training load is typically divided into two separate categories; external-, and internal training load (Bourdon et al., 2017, p. 161; Impellizzeri et al., 2004, p. 1042). The external training load refers to the work performed by an athlete, this load can be prescribed within a training plan explaining measures such as distance, velocity, duration, or load during strength training (Impellizzeri et al., 2019, p. 270). However, external training load can also be collected during training with different equipment. Internal training load refers to the individual's response to the work performed, however, this can also be prescribed to explain the desired intensity of an exercise or training (Impellizzeri et al., 2019, p. 270). Also here, the internal training load can be observed during their training. If the athlete can increase the external work with the same internal load this might reflect an increase in physical fitness. Likewise, if the athlete does the same amount of work with a reduced internal load this might also reflect an increase in physical fitness.

2.3.1 External Training Load

Along with the development of technology, access to external training load measures has improved (Cummins et al., 2013, p. 1026). Duration is a simple measure that has been used for a long time, however as video, accelerometer, gyroscopes, and GNSS have improved, several new measures have increased the availability of external training load measures (Cummins et al., 2013, p. 1026). From only discussing the duration of a match or a single training session, modern technology reveals forces acting on the athlete, actions performed, time spent- or distance covered in different speed thresholds (Bourdon et al., 2017, p. 163; Cummins et al., 2013, p. 1031).

Many of the measures discussed for modern football are made possible using variable GNSS and accelerometer, typically combined in one unit mounted on the player (Cummins et al., 2013, p. 1026; Miguel et al., 2021, p. 1; Scott et al., 2016, p. 1471). The GNSS is utilized to determine the precise location of the athlete, thus enabling the computation of the distance covered in various speed thresholds during their movements (Cummins et al., 2013, p. 1026). Additionally, the accelerometer detects the accelerations in the three different planes: sagittal, frontal, and transverse (Cummins et al., 2013, p. 1026). Together, these make a variety of measures used to get a better understanding of the external loads related to football (Miguel et al., 2021, p. 12). Here, distances can be presented as total distance (TD), or distances covered with specific thresholds (Miguel et al., 2021, p. 13). Accelerations in all three planes can be summarized to make the

PlayerLoad (PL), additionally, thresholds for accelerations can be made to determine the intensity of movements or to calculate the number of accelerations (Luteberget et al., 2018, p. 468; Miguel et al., 2021, p. 14).

For football, there are some frequently reported measures to represent the external training load (Barnes et al., 2014, p. 1096; Rave et al., 2020, p. 3). However, there are differences in thresholds used despite discussing the same measures (Algroy et al., 2021, p. 3; Buchheit et al., 2010, p. 819; Gabbett, 2015, p. 3356; Miguel et al., 2021, p. 13; Rave et al., 2020, p. 3). Still, there are no standards of what thresholds to use for the different levels of competition, age, or sex (Algroy et al., 2021, p. 3; Buchheit et al., 2010, p. 819; Gabbett, 2015, p. 3356; Miguel et al., 2021, p. 13; Rave et al., 2020, p. 3). Additionally, to different thresholds, there are variations in what measures that have been presented (Rave et al., 2020, p. 3). Despite this, it must be stated that typically presented measures are; total distance, high-speed distance, sprinting distance, and accelerations and decelerations (Buchheit et al., Algroy et al., 2021, p. 3; 2010, p. 819; Miguel et al., 2021, p. 17; Rave et al., 2020, p. 3). For younger athletes, Gabbett (2015, p. 3356) suggests using relative thresholds to better understand the individual training load, as the physical fitness differences are large during adolescence.

2.3.2 Internal Training Load

Similarly, as with external training load, there are several different measures to express the internal training load (Impellizzeri et al., 2019, p. 270; Miguel et al., 2021, p. 9). Also here, there has been an increase in measures as knowledge related to training has improved (Impellizzeri et al., 2019, p. 270). In contrast to the external categories that have been discussed for team sports, which predominantly rely on GNSS and accelerometer data to measure external training load for team activity, there exist various approaches to gain a more comprehensive insight into an individual's response to the training load (Miguel et al., 2021, p. 8).

The internal measures are typically classified into three categories (Miguel et al., 2021, p. 8). One category is the heart rate, either being presented as absolute beats per minute, relative to the maximal heart rate (%HR_{max}) divided into intensity zones or combined with the duration to make the training impulse (TRIMP) (Miguel et al., 2021, p. 8). However, they have limitations in terms of accuracy and variability due to factors such as environmental conditions, play situations, and individual differences in heart rate response (Impellizzeri et al., 2004, p. 1045). Therefore, it is important to consider these limitations when presenting and interpreting heart rate data to avoid overgeneralization or misinterpretation (Impellizzeri et al., 2004, p. 1045). On the other hand, heart rate can easily be included as it does not require anything from the athlete except wearing a heart rate monitor. Along with standardized training protocols, it might detect changes in physical fitness for the individual (Rave et al., 2020, p. 8). Another category is biomarkers which can be detected in blood and spit, among others, where either an increase or reduction among different substances will reflect the response to training for either an acute or a prolonged period (Miguel et al., 2021, p. 10). For example, may the level of creatine kinase in the blood indicate to what level the athlete has recovered from a match (Rave et al., 2020, p. 8). Measuring the blood lactate acid might indicate the relative intensity of the athlete´s recent activity (Bangsbo et al., 2007, p. 113). Likewise, as with heart rate, biomarkers will give an objective measure of the athletes to better understand response and adaptation to training load (Miguel et al., 2021, p. 2). However, data collection might be time-consuming and expensive to perform on larger teams where standardized levels are lacking, due to large individual differences (Miguel et al., 2021, p. 2). The last, out of the three categories, are questionnaires where the athlete rates their perceived exertion (RPE) from a session or reflects on how their overall wellness or readiness among other self-reported factors at a given time (Foster et al., 2001, p. 109; Miguel et al., 2021, p. 11). Session RPE (sRPE) was introduced to have an additional factor when monitoring various types of training by rating exertion from 0-10, here 0 represents rest and 10 represents maximal effort (Foster et al., 2001, p. 111). Additionally, the duration of the training was multiplied with the RPE making the sRPE-TL (Foster et al., 2001, p. 113; Impellizzeri et al., 2004, p. 1043). RPE and questionnaires are useful methods for assessing internal training load response within football due to their ease of administration and cost-effectiveness (Impellizzeri et al., 2004, p. 1046). However, their subjective nature and potential for inconsistent responses should be taken into consideration when interpreting the data (Impellizzeri et al., 2004, p. 1046).

Similarly, as with external training load, there is a wide variety of categories being reported, however, questionnaires and heart rate seem to be most commonly used (Miguel et al., 2021, p. 17). Then again, it should be noted that these categories make a large variety of measures, with RPE and TRIMP being the measures most frequently reported (Miguel et al., 2021, p. 17).

As training load can be explained in several different categories and measures, there is no golden standard to what measures to use, as this depends on the type of training performed (Impellizzeri et al., 2019, p. 270). Therefore, it is important to highlight the importance that both external-, and internal training load should be considered together to better understand training load and individual response (Impellizzeri et al., 2019, p. 273).

2.4 Physical Fitness Development During Adolescence With Training Stimuli

As physical demands related to football, training load, and changes during adolescence have been described previously, this section will focus on the development that occurs with training stimulus during adolescence. Studies reveal that adult athletes perform better compared to youth athletes in physical qualities such as speed, jumping, agility, strength, and endurance (Gabbett, 2002, p. 336; Kelly et al., 2017, p. 3062). Therefore, it will be of interest to better understand how athletes during adolescence should train to better improve their physical fitness. Additional to studies analyzing an intervention for a certain time, adaptations to training load on the field will be discussed.

2.4.1 Speed

Speed is described as the neuromuscular system's ability to create both horizontal and vertical accelerations (Gjerset et al., 2015, p. 443). Here, rapid and maximal activation of the relevant muscles, in addition to the muscle’s capabilities in terms of muscle composition of type II fibers, pennation angle, length, and the cross-sectional area seems to be of importance (Raastad et al., 2010, p. 226). Furthermore, speed can be divided into several categories: acceleration-, maximal-, and endurance speed (Schoenfeld & Snarr, 2021, p. 466). The different speed categories will differ in importance related to playing position as each position has different demands (Varley et al., 2017, p. 22). Speed is an important factor in football as it will determine vital situations when either scoring a goal, preventing a turnover, or making a tackle (Varley et al., 2017, p. 25). As there are some differences in the speed categories, they are also being tested in a different scenario or with different distances (Buchheit et al., 2010, p. 2717; Gabbett, 2002, p. 336; Grendstad et al., 2020, p. 256; Wrigley et al., 2014, p. 1091). Often, both acceleration and maximal speed are determined by a 30-m or 40-m sprint, where the first 10-m represents the acceleration phase and the best split-time from the fastest 10-m represents the maximal speed (Grendstad et al., 2020, p. 257). Endurance sprint describes the ability to either maintain speed for a longer period (> 6 seconds), or the ability to maintain speed with repeated sprints, this is commonly tested by intermittent sprints when testing football players (Buchheit et al., 2010, p. 2716; Schoenfeld & Snarr, 2021, p. 466).

Several studies found that performance in sprinting increases with chronological age (Gabbett, 2002, p. 336; Greier et al., 2019, p. 262; le Gall et al., 2010, p. 92; Williams et al., 2011, p. 267). However, there might be an indication of players reaching their maximal speed during late adolescence without further increase with age, however, this might also reflect selection to elite teams rather than still playing for academy teams for this study (Smalley et al., 2021, p. 136). When looking at sprinting performance in a match, similar findings apply as both top velocity, sprinting distance and accelerations increased with age (Buchheit et al., 2010, p. 819). Additional to increasing speed with age, it is shown that athletes during adolescence will improve performance when taking part in interventions to increase their speed abilities (Buchheit et al., 2010, p. 2717; Lockie et al., 2012, p. 1543). When studying athletes for a longer period, it seems as if there is an additional benefit with a higher training volume, compared to a lower training volume, during adolescence (Wrigley et al., 2014, p. 1092).

2.4.2 Agility

Agility is a complex movement combining acceleration, deceleration, reacting to a stimulus, and CoD (Sheppard & Young, 2006, p. 919). Despite agility is defined as a response to stimulus, testing is often conducted without this variable to make it more standardized – bringing it closer to a CoD test (Stewart et al., 2014, p. 501). It would be easy to assume that abilities similar to speed will be relevant, however, Sheppard & Young (2006, p. 923) found only weak or moderate correlations between sprinting, leg strength, and leg power. However, this correlation is depending on how many turns the agility- or CoD test has as this results in different demands. Football is an open sport where the players need to adapt rapidly to many stimuli, such as the opponent, teammates, and the ball. Therefore, agility is important for football players as they perform more than 500 turns defined as purposeful movement, where the majority of these are performed between 0° - 90° (Bloomfield et al., 2007, p. 68). Agility is also proven to be an important physical test that separates levels between youth players (Reilly et al., 2000, p. 698).

Similarly, as with speed, CoD performance increases with age (Figueiredo et al., 2009, p. 66; Lloyd et al., 2015, p. 15). Despite the increase with age, it seems to reach a plateau and might even decrease with an increase in age (Loturco et al., 2020, p. 1283). Despite some studies do not find improved performance, overall, there seems to be an increase in performance with training either specifically for CoD or less specific (Hammami et al., 2017, p. 5; Thieschafer & Busch, 2022, p. 17). For adults, agility performance seems to not increase with increased strength, however, for young athletes an increase in strength seems to enhance performance further compared to development from growth and maturation alone. (Thieschafer & Busch, 2022, p. 18). Still, the principle of specificity stands strong to improve agility (Lesinski et al., 2020, p. 1925; Thieschafer & Busch, 2022, p. 18). During longitudinal studies performance increased with age (Bidaurrazaga-Letona et al., 2015, p. 236), furthermore, there seems to be an additional increase in performance with a high training volume compared to low training volume (Wrigley et al., 2014, p. 1092).

2.4.3 Jumping

Jumping can be divided into horizontal-, and vertical jumping (Raastad et al., 2010, p. 225). Similarly to speed, rapid and maximal activation of the lower limb muscles is necessary to produce as much power as possible, in a short period (Raastad et al., 2010, p. 225). The ability to jump high will benefit gameplay as this might result in either scoring or preventing turnovers by beating the opponent in a dual. Jump performance also reflects the relative power production in the legs in a more familiar manner compared to movements with equipment or free weights (Paul & Nassis, 2015, p. 1755). Two commonly used methods are the squat jump and countermovement jump (CMJ) as they are both time efficient and easy to administrate (Paul & Nassis, 2015, p. 1750). Still, the CMJ is more commonly tested as this often feels more natural and is more similar to sports as this is a plyometric movement compared to jumping from a static start (Paul & Nassis, 2015, p. 1755). Using a force plate is seen as the golden standard for testing jump performance as this uses ground reaction forces to determine the height (Toft Nielsen et al., 2019, p. 9).

Similarly to speed, many studies show an increase in jumping performance with an increase in chronological age, but the differences seem to be smaller as they get older (Buchheit et al., 2010, p. 819; le Gall et al., 2010, p. 92; Loturco et al., 2020, p. 1281; Williams et al., 2011, p. 267). When training specifically to improve jumping performance, football players during adolescence seem to increase jumping performance (Buchheit et al., 2010, p. 2717). Also, when testing the same athletes for a prolonged period they increase their performance with age, and when comparing academy to non-academy players the higher training volume for the academy players resulted in greater improvement (Wrigley et al., 2014, p. 1092).

2.4.4 Strength

Strength is defined as "the maximal force or torque a single muscle or a muscle group can create from a specific or predetermined velocity" (Raastad et al., 2010, p. 13). Furthermore, strength can be divided into maximal strength, producing high force from a low contraction velocity, or explosive strength, producing high power from a high contraction velocity (Raastad et al., 2010, p. 13). Important factors for strength are combined by both the muscle and the central nervous system (Raastad et al., 2010, p. 19). Variables important for strength related to the muscles are; physiological cross-sectional area, pennation angle, and muscle composition, whereas variables important for the central nervous system are; coordination and level of activation of the muscles (Raastad et al., 2010, p. 19). As previously described, these are variables important for speed, jumping and CoD, additionally, strength might benefit players as football is a sport allowing physical contact during tackles. Maximal strength can be tested during a one repetition maximum (1RM) in a given exercise with a given range of motion, on a force platform, isometric in a fixed position, or isokinetic in a movement controlled eccentric or concentric (Redden et al., 2018, p. 539; Raastad, 2010, p. 143). Explosive strength can also be tested on a force platform during a jump, Keiser leg press, or isokinetic in concentric movement (Raastad et al., 2010, p. 145; Redden et al., 2018, p. 539).

Strength increases during adolescence, more for boys compared to girls, however, they both seem to have an additional increase when adding resistance training (Armstrong & Mechelen, 2017, p. 494; Lesinski et al., 2020, p. 1927). Mainly, the additional improvement by adding resistance training seems to be an improvement of the central nervous system rather than the muscles, even though it is discussed that with prolonged studies with higher volume, more adaptations will occur in the muscles as well (Armstrong & Mechelen, 2017, p. 494).

2.4.5 Endurance

Endurance is described as “the ability to work with a relatively high intensity for a given time” (Gjerset et al., 2015, p. 270). It is therefore important to produce much energy and/or reduce the cost, which is why the circulation system, work economy, and utilization rate are important (Stolen et al., 2005, p. 522). The main energy system utilized in a match is the aerobic system, however as the anaerobic movements seem to be of such importance this energy system must also be emphasized (Stolen et al., 2005, p. 522). As football is an intermittent sport, testing should also be performed in this manner (Bangsbo et al., 2008, p. 37). Commonly the Yo-Yo intermittent recovery (YYIR) test 1 or 2 is used to test football-specific endurance as this test includes sharp turns, short brakes, and “shorter” distances covered over an increasing intensity (Bangsbo et al., 2008, p. 38).

Performance in YYIR-1 increased with age (Bangsbo et al., 2008, p. 43). When testing maximal oxygen consumption by comparing one endurance- and one non-endurance group during adolescence for a prolonged period there was no difference in the increase of maximal oxygen consumption (Landgraff, 2020, p. 32). However, when comparing the time to exhaustion the boy endurance group increased close to 3 times more compared to the boys in the non-endurance group, whereas there were no differences between the girl groups (Landgraff, 2020, p. 44). Despite the endurance group already performing best from baseline, they were also the group to increase the most. Similar findings apply when comparing academy players to non-academy players, here the academy players performed better at baseline but were also the ones to increase their performance the most. (Landgraff, 2020, p. 44; Wrigley et al., 2014, p. 1092).

3. Method

The method chapter is meant to give a better understanding of what has been done to respond to the research question. Firstly, study design will be described followed by presenting the participants and inclusion criteria. Later, the ethics related to the study will be presented before describing the test battery and how training load was collected. Lastly, the statistical analyses will be described.

3.1 Study Design

This master thesis is a part of a larger study. The larger study is a longitudinal study that started in late 2021 and is expected to be finished by the summer of 2024. The larger study will examine many factors (training load, injuries, physical fitness) related to getting a better understanding of how football and handball athletes train and evolve during adolescence. This thesis will focus on training load, both external- and internal load, and the development of physical fitness for football players over one year. This chapter, method, will only describe tests and how data were managed for this thesis. Data available at the end of 2022 will be used for this thesis.

Data collection consisted of both physical testing and monitoring of the training load. Pre-testing was performed about one year before post-testing. Training loads were collected over three periods over one year, each period lasting two-weeks. The intention of this was to get a broader range of their common training load throughout the year as this might vary within a season. Objective training loads were only conducted during organized football sessions and matches, whereas subjective training load was to be submitted from every activity performed throughout the two-weeks period.

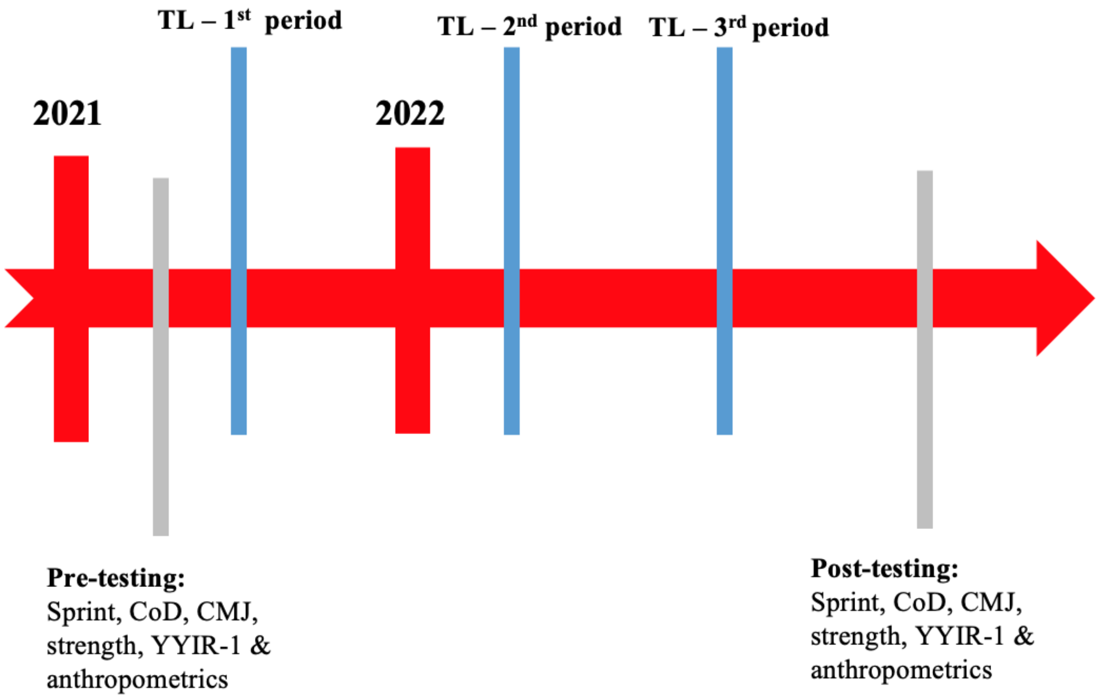


Figure 3.1: Predetermined plan for testing and collection of the training load. Further data will be collected after post-testing, this will not be included in this thesis. Therefore, this figure shows the data collection relevant for this thesis. One period consists of two-weeks. TL – Training Load; CoD – Change of Direction; CMJ – Countermovement Jump; YYIR – YoYo Intermittent Recovery test.

3.2 Participants and Inclusion Criteria

The study recruited both boys and girls actively playing football at the age of 13-, 15- and 17 years of age. Athletes were recruited from teams in Oslo, Norway. Teams were selected with the idea to monitor teams with different training load and levels of competition. Players from all positions, except keepers due to their difference in physical fitness demands and external training load during training and matches (Di Salvo et al., 2008, p. 444), were recruited. All participants were to report their subjective training load for everyday activity, in addition to the objective measures collected using a wearable GNSS during the football sessions for the selected periods. The participants also completed two test batteries, giving pre- and post-results. To be included, the subject had to take part in 60% or more of the football sessions for at least two out of the three periods for data collection. Additionally, subjects had to have both pre- and post-results from at least one test. No inclusion criteria were made for reporting subjective training load, sRPE. Descriptive data of the included participants are presented in Table 3.1.

Table.3.1: Descriptive data of the included participants from the beginning of the study (2021). Values are shown as average ± standard deviation (SD).

Sex	Age (years)	Height (cm)	Weight (kg)	Quantity (n)
Male	14.4 ± 1.6	164.3 ± 11.2	52.3 ± 13.1	16
Female	14.4 ± 0.9	165.4 ± 5.8	57.5 ± 5.2	12

3.3 Ethics Statement

All participants have signed an informed letter agreeing to participate, being aware of both the risks and the protocol for the study, and additionally, information about how their data will be stored and used to establish new knowledge (Appendix III). Additionally, the guardians of the participants below sixteen years of age also had to sign, agreeing to participate. All participants are allowed to review their data and drop out of the study at any time. It will not be possible to identify the participants as we are using numbers as ID, while only certified personnel will have access to the name list. All data related to the study, including ID, will be stored for five years before being erased. The larger study was approved by "norsk senter for forskningsdata" (NSD) and the Norwegian School of Sport Science ethical committee. Assessments from NIH ethical committee and NSD are shown as appendices (Appendix I and Appendix II).

3.4 Measurement of Physical Fitness and Anthropometrics

The test battery was carefully selected to measure physical fitness related for football players, additionally to anthropometrics. The physical tests were therefore selected to get information about abilities of importance during play situations, whereas the anthropometrical measures were meant to measure the characteristics of the players. The abilities that were being tested were; speed, jumping, strength, and endurance. The tests were performed on two separate days. Day 1 consisted of measuring anthropometrics before performing a standardized warm-up controlled by a coach familiar with the testing. Following the warm-up were sprinting and then CoD, before the remaining tests were in a random order making it more time efficient. Day 2 consisted of a voluntary warm-up controlled by a coach before completing the endurance test. All tests during day 1 were performed with the same equipment with the same protocol for both pre- and post-testing. The endurance test on day 2 was performed inside, however, due to logistics the endurance test was completed in different sport halls. Still, an effort was made to get both pre- and post-testing within the same location, despite not always being possible. Athletes were encouraged to use inside shoes for all physical tests. During all physical tests, athletes were verbally encouraged to give their best by the test leaders.

3.4.1 Sprint

Athletes line up with their front foot placed 50 centimeters behind the first photocell. Followed by a “good” signal from the coach, the athletes voluntarily starting their sprint. To ensure standardized testing procedures, all athletes completed their first run, in a predetermined order, before all athletes proceeded to their second and then third run. To minimize fatigue, a rest interval of at least three minutes was provided between each run for all athletes. Sprint was tested with a 30-meter linear sprint, timings were collected at 10-m, and 30-m by photocells. The top speed was determined from their fasted 10-m interval. From previous studies, both acceleration and top speed seem to be important in crucial moments during match play (Barnes et al., 2014, p. 1099; Stolen et al., 2005, p. 509). Sprint performance also seems to give valid information about the external work performed during small-sided and large-sided gameplay (Castillo et al., 2020, p. 200). The photocells used, Athletics Trainer System (IC control Media & Sport, Bromma, Sweden), were mounted inside a gym where the running track is closed off during testing. To ensure consistency in surface and conditioning, all athletes conducted their sprints at the same location. The 30-meter sprint test has an ICC of 0.90-0.97 making it a reliable test for young football players (Lopez-Segovia et al., 2015, p. 132; Loturco et al., 2017, p. 607).

3.4.2 Change of Direction (OLT40 Agility Test)

Similar to the sprint test, athletes started voluntarily 50 centimeters behind the first photocell. While facing the finish line 20 meters ahead, the athletes are to run a total of 40 meters with four 180˚ turns, all turns performed with the same foot. Each athlete completes a total of four runs divided into two right-footed turns and two left-footed turns. Like sprinting, athletes completed their runs in order with a minimum of three minutes rest. The CoD test is a modified version of the S180˚ (Sporis et al., 2010, p. 682). Similar as with sprinting, rapid change of directions seems to be an important aspect of football as this might help interfere with a counterstrike or benefit players during duals in both offensive and defensive play situations (Bloomfield et al., 2007, p. 68; Reilly et al., 2000,

p. 698). The CoD tests were performed in the same place with the same equipment as with sprinting. Despite minor differences from the S180˚ by Sporis et al. (2010, p. 682), this test will be considered a reliable test, as the original test had an ICC of 0.94.

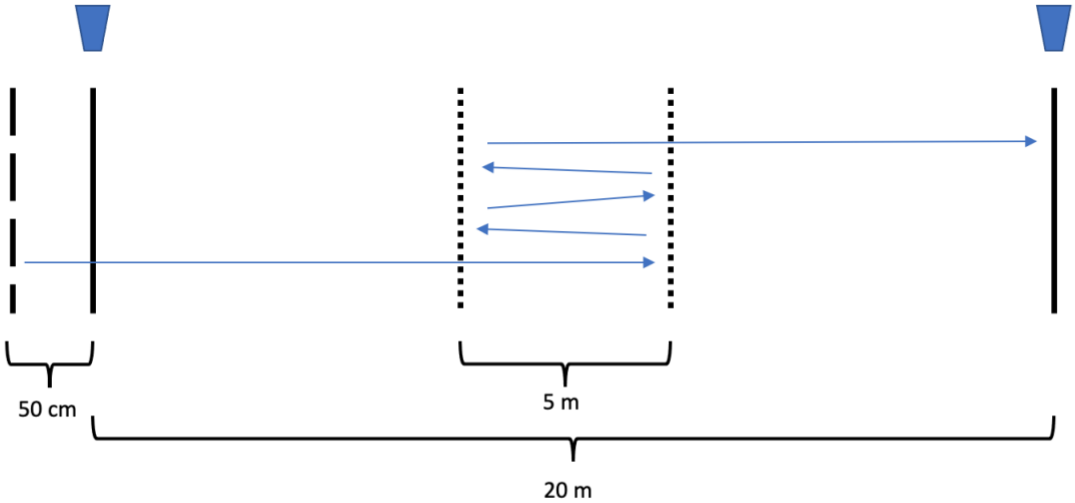


Figure 3.2: OLT40 Agility Test. The blue trapeses illustrate the positioning of the photocells, start and finish. The striped lines indicated the start of the course, as the front foot was placed 50 cm behind the first photocell. The dotted lines indicate the lines where the athletes had to turn. The blue arrows indicate the running course for the athletes, despite the illustration might indicate a shift upwards this is only to show the four turns completed on the same foot.

3.4.3 Jump Height (Countermovement Jump)

The athletes performed their jumps with their hands placed on their hips throughout the entire movement. They were instructed to stand in an upright position with a shoulder-width stance and perform their jump as fast and powerful as possible. They moved down to a self-selected depth before rapidly moving on to the concentric phase. Originally, a total of three attempts were given, with short rest in between. However, if they improved drastically, they were allowed to continue until reaching a plateau. Few instructions were given during testing, with exceptions where coaches felt this might benefit the athlete. Vertical jump height was tested with CMJ on a force platform (HUR Labs Oy, Tampere, Finland). The CMJ test is meant to reflect the demands of both power production and the neuromuscular ability to perform explosive and rapid movements during play situations (Requena et al., 2009, p. 1391; Raastad et al., 2010, p. 225). The CMJ has been proven to be a valid measure of power production (Liebermann & Katz, 2003, p. 90). As there are many ways of testing explosiveness and power production this is a known movement, making it easier for the athletes (Paul & Nassis, 2015, p. 1755). Despite some differences from jumping during game situations, the CMJ also tests the coordinative components of jumping which also might be affected during adolescence (Corso, 2018, p. 153). CMJ has been proven to have good reliability from day to day with a coefficient of variation (CV) of 5.0% (Cormack et al., 2008, p. 138). The force platform uses ground reaction forces to calculate the height which has shown to be a reliable measurement with an ICC >0.90 (Heishman et al., 2018).

3.4.4 Keiser Leg Press

Leg strength, force and power, were measured in the Keiser Leg Press (A300, Keiser Co. Inc.). The leg press machine uses air pressure (pneumatic) for resistance (Redden et al., 2018, p. 540). The test used is Keiser´s 10RM protocol. Before starting the test, the test leader estimates the athlete's 1RM based on either previous testing or similar athletes. The test starts with two repetitions for familiarization and warm-up with low resistance, after this, the resistance automatically increases for every repetition until failure. As the resistance increases, the pauses between repetitions also increases slightly for every repetition. The 10^{th} repetition is the predetermined estimated 1RM, however, if the player can perform the 10^{th} repetitions the protocol continues with increased resistance and matching pause in-between repetitions. The athletes are instructed to perform every single repetition with the intention to move as rapidly and powerfully as possible. Both muscle strength and power are shown to be central components as their both shown to be important abilities as a football player (Cometti et al., 2001, p. 47; Requena et al., 2009, p. 1391; Raastad et al., 2010, p. 225). Given the frequent changes in direction and forces associated with running, accelerating, and decelerating during athletic competition, relative strength becomes a critical factor in enabling athletes to effectively control their body weight (Stolen et al., 2005, p. 518). Rather than focusing on absolute strength, relative strength might have better implications as subjects during this study vary in mass due to the large variation of growth during puberty (Malina & Koziel, 2014a, p. 426; 2014b, p. 1378). This test has shown good inter-reliability for maximal force, maximal power, and average power, respectively; ICC:0,914, ICC:0,886, and ICC:0,886 (Redden et al., 2018, p. 540).

3.4.5 YoYo-Intermittent Recovery Test 1

Football-specific endurance was measured with the YYIR-1. The test consists of both a “running” and an active recovery part. The time during active recovery, 2 x 5m, remains constant at 10 seconds, whereas the time moving, 2 x 20m, decreases in levels with time. The athletes will get a warning if they start before the signal, do not touch the line before turning, or if they do not reach the finish in time. Throughout the test, they can get one warning, but they were taken out of the test as they got their second warning. If the athletes manage to start, but not finish, they will get that as a counting lap. This test is designed to simulate the intermittent and rapid change of direction aspects of football (Bangsbo et al., 2008, p. 38; Stolen et al., 2005, p. 522). The test has previously been shown to correlate well with distances covered in matches for both HSR and TD (Castagna et al., 2009, p. 1956; Krustrup et al., 2003, p. 703). The setup for the track and audio are both standardized. The test has been proven to have good reliability with ICC of 0,87-0,95 and CV: 4,9% (Deprez et al., 2015, p. 66; Krustrup et al., 2003, p. 700). The track was set with the help of measuring tape and cones. The total distance ran was calculated from how many laps they had completed.

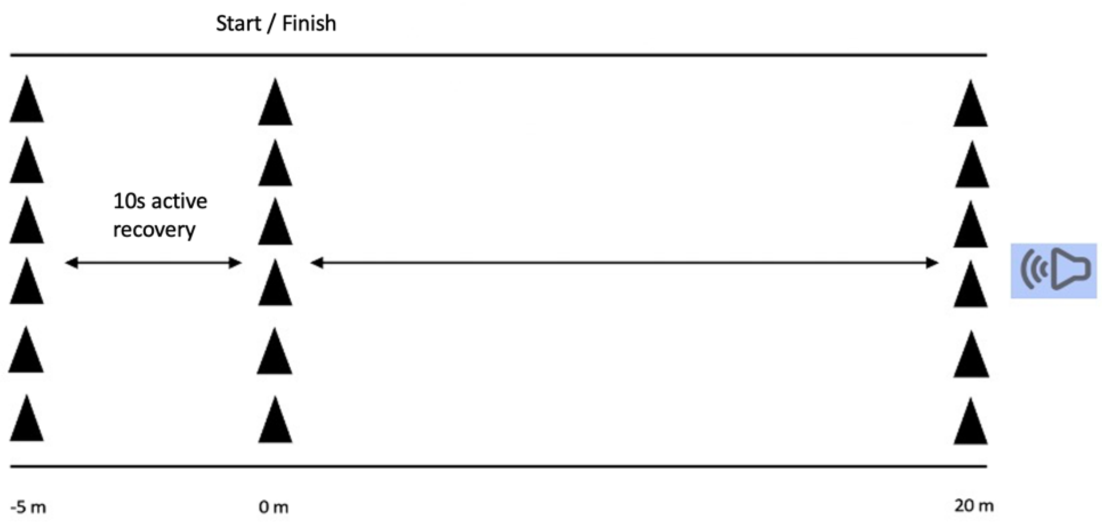


Figure 3.3: YoYo Intermittent Recovery test 1 track.

3.4.6 Anthropometrics

When measuring anthropometrics, the athletes wore the clothes used when testing, but without their shoes. Height was measured using a stadiometer (Seca, Hamburg, Germany). Weight was measured using a digital scale (Seca, Hamburg, Germany). Height and weight were measured to the nearest 0.1 cm or 0.1 kg. Both measures were collected twice to ensure good data where the average was used. However, if the measurements had a larger difference than 0.2cm or 0.2kg a third measure was implemented, here the median was used (Mirwald et al., 2002, p. 690).

3.5 Collection of Training Load Data

3.5.1 Internal Training Load

During their 2-weeks periods, they were instructed to rate their sRPE and state the duration of every training session completed. They reported individually with their smartphone, using the application Athlete Monitoring (Moncton, Canada). For internal training load throughout this study, sRPE was collected and multiplied with the duration of the training session making the sRPE-TL (Foster et al., 2001, p. 113; Impellizzeri et al., 2004, p. 1043). sRPE-TL has been proven to correlate with external variables, TD ($r=0.81$, $p<0.05$), HSR ($r=0.71$, $p<0.05$), and (PL)($r=0.83$, $p<0.05$) (Scott et al., 2013, p. 270). Additionally, it has been shown to be both a valid and reliable measure of internal training load for youth football players (Impellizzeri et al., 2004, p. 1046; Vahia et al., 2019, p. 97). Therefore, sRPE-TL gives us a better understanding of their training load without needing to take part in training sessions outside team football sessions.

3.5.2 External Training Load

The external training load will be monitored using the GNSS-units OptimEye S5 (10Hz) (Catapult Sports, Melbourne, Australia). These units are equipped with an inertial measuring unit (IMU) made out of an accelerometer (100Hz), gyroscope (100Hz), and magnetometer (100 Hz). For every football session, training or match, the athletes wore a customized vest placing the GNSS in between the scapulae. Additional to measuring the positioning of the player, the IMU will measure PL and high-intensity efforts throughout the session (Luteberget et al., 2018, p. 468).

Throughout the study, we endeavored to provide all students with the same GNSS throughout the course to reduce the inter-variability within different units, this despite all units were from the same brand (Malone et al., 2017, p. 18; Roe et al., 2017, p. 639). Few studies have investigated the reliability and validity of the OptimEye S5, however, the GNSS unit seems to have moderate to good validity at 10Hz when measuring maximal sprinting velocity with a typical error of estimate of 1.87-1.95% (Roe et al., 2017, p. 838). However, the previous version of MinimaxX has been tested showing good validity for TD and HSR, CV: 1,9% and 4,7%, respectively (Rampinini et al., 2015, p. 51). For high-intensity efforts $>2{,}5 m*s^{-2}$ and PL, the IMU show reliable data with CV of 3.1% and 0.9-1.7%, respectively (Luteberget et al., 2018, p. 469).

From the wearable GNSS, several external measures will be collected to get a better understanding of the work performed during sessions for each player. Which parameters and what thresholds to use are disputed within youth football (Vieira et al., 2019, p. 302). Therefore, HSR is set to 13–18 km/h, sprinting had two thresholds; one set to 18-25.2km/h and another above 25.2 km/h, however, no subjects included in the statical analyses reached the highest threshold. Acceleration and deceleration were set to 2 m/s^2 giving the numbers of high-intensity efforts (HIE). Additional to these measures with clear thresholds, total distance, duration, and PL will be collected.

As this study include a variety of players both related to sexes, age, and level, relative thresholds will also be used. Velocities at 70% of maximal velocity or above have previously been used to categorize sprinting (Gabbett, 2015, p. 3357). For this study, this threshold was divided into three measures; 70-80% (low relative sprinting, LRS), 80-90% (medium relative sprinting, MRS), and 90-100% (high relative sprinting, HRS) to get a better understanding of what level of sprinting they reached. For this study, the maximal velocity was determined from the fastest 10-m split from the 30-m sprint test.

3.6 Statistical Analyses

All statistical analyzes were performed in GraphPad Prism (9.5.1.(528)). All the results are presented as average ± standard deviation as all the data were normally distributed. The normal distributions were analyzed from a visual perspective from histograms. Training load measures are presented as average training load per period for one player for both sexes. The statistically significant level for all the results was set to $p<0.05$. For test results, paired t-tests were performed to investigate differences from pre- to post-tests within the same sex, however, unpaired t-tests were performed to investigate the differences between the sexes. For percentage change from pre- to post-tests, unpaired t-tests were performed to investigate the differences in development between sexes. Similarly, unpaired t-tests were performed for training load to investigate differences between sexes. Lastly, training load measures and percentage change for each subject were correlated to investigate the relationship between development in physical fitness related to training load. For this study, correlation values ranging from 0.50 to 0.70 were considered moderate, whereas values >0.70 were considered strong.

4. Results

4.1 Physical Fitness and Anthropometrics

Anthropometrical measures did not differ between sexes, however, both sexes increased in both height and weight from pre- to post-testing (Table 4.1). In total, girls improved performance in four physical tests from pre- to post-testing, whereas boys improved in all nine tests. For 10-m, 30-m, and CoD there were differences between sexes at both pre- and post-testing, additionally, they both improved from pre- to post-testing (Table 4.1). Regarding CMJ, relative force, and relative power boys performed better during pre- and post-testing, boys also improved from pre- to post testing whereas girls did not improve (Table 4.1). For YYIR-1, boys and girls performed similarly during pre-testing, however, boys improved from pre- to post testing, which resulted in differences between sexes during post-testing (Table 4.1). Total force follows the patterns of anthropometrics, where both groups improved from pre- to post-testing despite no differences between sexes (Table 4.1).

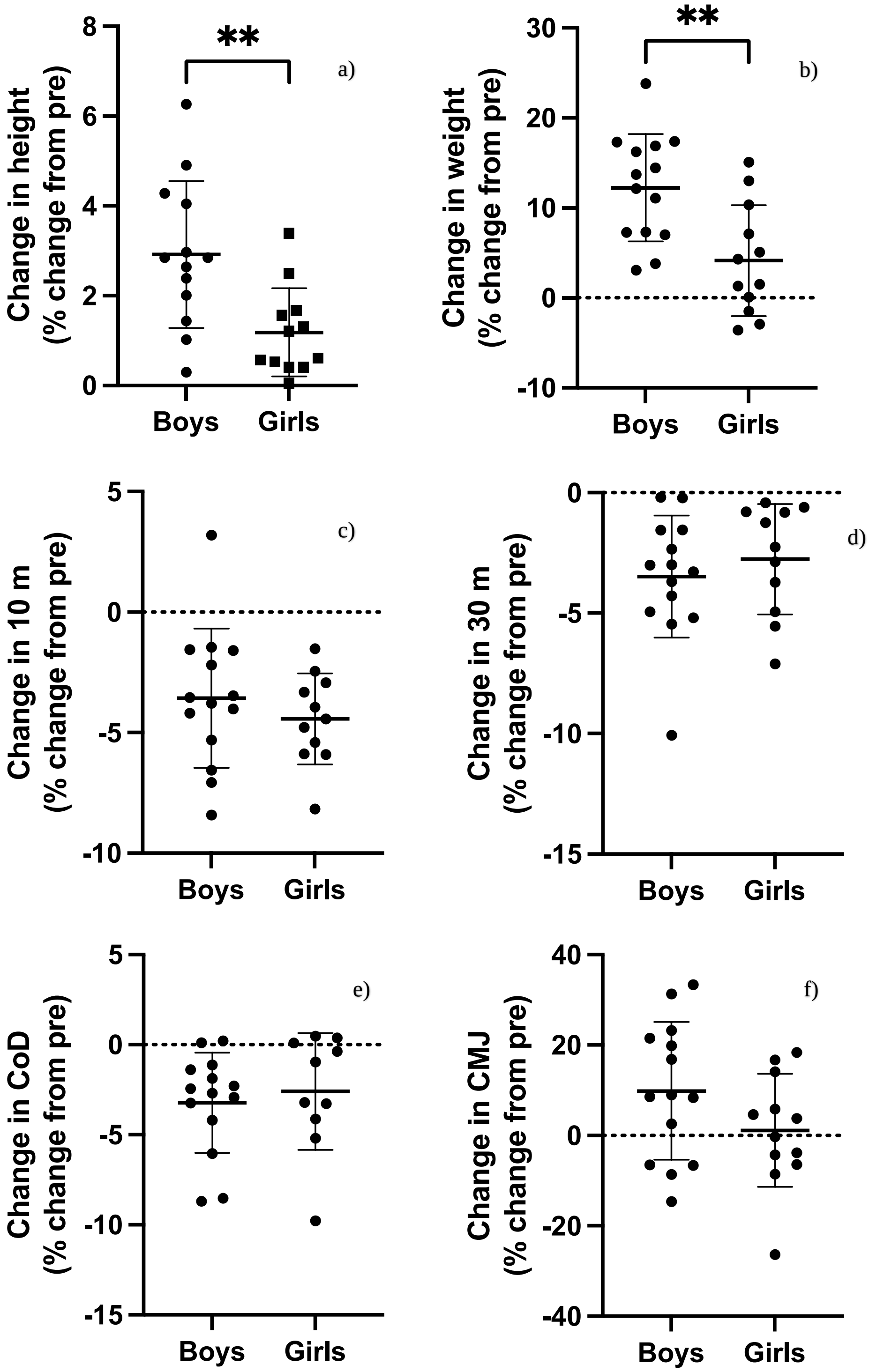
Table 4.1: Results for pre- (2021) and post-testing (2022) for anthropometrical and physical fitness characteristics. Values are shown as average ± standard deviation.

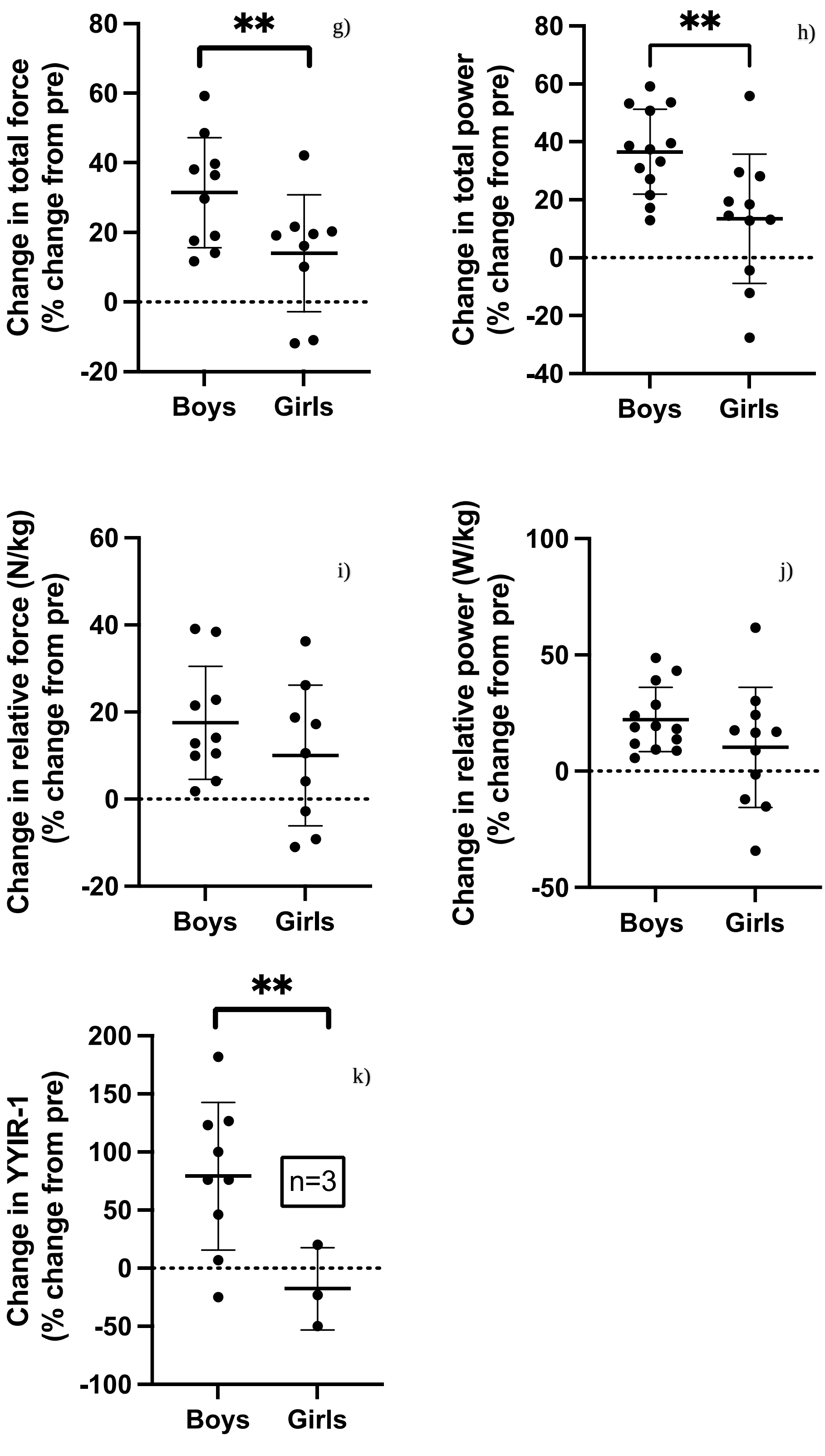
	Pre (2021)	Post (2022)
Height (cm)		
Boys (n=13)	162.8 ± 11.2	167.5 ± 10.0$
Girls (n=12)	165.4 ± 5.8	167.3 ± 5.9$
Weight (kg)		
Boys (n=14)	50.7 ± 12.8	56.7 ± 13.0$
Girls (n=12)	57.5 ± 5.2	59.7 ± 5.6$
10 m (s)		
Boys (n=14)	1.95 ± 0.10*	1.88 ± 0.10*$
Girls (n=11)	2.08 ± 0.07	1.99 ± 0.06$
30 m (s)		
Boys (n=14)	4.67 ± 0.26*	4.50 ± 0.28*$
Girls (n=11)	5.00 ± 0.22	4.86 ± 0.17$
CoD (s)		
Boys (n=14)	10.10 ± 0.57*	9.77 ± 0.44*$
Girls (n=10)	11.01 ± 0.39	10.71 ± 0.29$
CMJ (cm)		
Boys (n=14)	32.8 ± 4.5*	35.7 ± 5.1*$
Girls (n=12)	28.0 ± 3.3	28.2 ± 4.8
Total Force (N)		
Boys (n=10)	2 093 ± 651	2 689 ± 698$
Girls (n=9)	1 909 ± 342	2 164 ± 456$
Total Power (W)		
Boys (n=13)	831 ± 288	1 120 ± 373*$
Girls (n=11)	723 ± 146	812 ± 202
Relative Force (N/kg)		
Boys (n=10)	38.8 ± 5.0*	45.1 ± 3.4*$
Girls (n=9)	33.0 ± 4.5	36.1 ± 6.1
Relative Power (W/kg)		
Boys (n=13)	16.3 ± 2.6*	19.7 ± 2.5*$
Girls (n=11)	12.5 ± 2.2	13.6 ± 3.3
YYIR – 1 (m)		
Boys (n=9)	836 ± 621	1 258 ± 251*$
Girls (n=3)	600 ± 250	440 ± 40

* = Significant difference from girls ($p<0.05$), $ = significant difference from pre- to post-testing ($p<0.05$). CMJ – countermovement jump; CoD – change of direction; N – newton; YYIR – YoYo intermittent recovery test; W – watt.

4.2 Development in Physical Fitness and Anthropometrics

Boys had greater percentage development in both height (2.9% vs. 1.2%) and weight (12.3% vs. 4.2%) compared to girls (Figures 4.2a & b). Similarly, boys also had greater development in total force (31.4% vs. 14.0%), total power (36.6% vs. 13.5%), and YYIR-1 (79.1% vs. -17.7%) compared to girls (Figures 4.2g, h & k).





Figures 4.1a-k: Percentage change in; height (a), weight (b), 10 m (c), 30 m (d), CoD (e), CMJ (f), total force (g), total power (h), relative force (i), relative power (h), YYIR-1 (k) for both sexes. Values are shown as percentage change from pre-testing. **Significant difference (p<0.05) from girls. CMJ – countermovement jump; CoD – change of direction; N – newton; YoYo intermittent recovery test; W – watt.

4.3 Training Load

Boys had significantly higher load of sprinting distance (102%), sprinting efforts (89%), and HIE (101%) compared to girls for the two-weeks training period (Table 4.2). In contrast, the remaining training load measures were similar between sexes (Table 4.2).

Table 4.2: Average training load per period (2 weeks) for one player. Values are shown as average ± standard deviation.

	Average training loads per period
Boys	n = 16
Girls	n = 12
Duration (min)	
Boys	400 ± 120
Girls	394 ± 100
Total Distance (m)	
Boys	26 160 ± 9 965
Girls	23 957 ± 8 501
Total PlayerLoad (au)	
Boys	3 247 ± 1 438
Girls	2 358 ± 840
High-Speed Running Distance (m)	
Boys	2 674 ± 1 471
Girls	2 339 ± 1 274
Sprinting Distance (m)	
Boys	947 ± 620*
Girls	468 ± 266
Low Relative Sprinting Distance (m)	
Boys	427 ± 285
Girls	411 ± 294
Medium Relative Sprinting Distance (m)	
Boys	167 ± 112
Girls	159 ± 120
High Relative Sprinting Distance (m)	
Boys	50 ± 40
Girls	48 ± 70
High-Intensity Efforts (n)	
Boys	543 ± 252*
Girls	270 ± 113
Efforts of High-Speed Running (n)	
Boys	280 ± 143
Girls	235 ± 111
Efforts of Sprinting (n)	
Boys	68 ± 42*
Girls	36 ± 19
Low Relative Sprinting Efforts (n)	
Boys	58 ± 40
Girls	61 ± 45
Medium Relative Sprinting Efforts (n)	
Boys	16 ± 11
Girls	16 ± 14
High Relative Sprinting Efforts (n)	
Boys	3.8 ± 3.1
Girls	3.8 ± 6.3
sRPE-TL (au)	
Boys	1 105 ± 960 (n=14)
Girls	1 525 ± 752

* Significant difference from girls ($p<0.05$). au – arbitrary unit; sRPE-TL – session rating of perceived exertion training load

4.4 Relationship Between Training Load and Change in Physical Fitness

Several measures of training load and change in physical fitness tests correlated significantly (Table 4.3). In total, boys had eleven correlations, whereas girls had thirteen correlations being statistically significant (Table 4.3). Here, total power was the test that correlated significantly with the highest number of training load measures, six measures in total (Table 4.3). Furthermore, sprinting distance, efforts of HSR, efforts of sprinting, and efforts of HRS were the measures of training load correlating significantly with the highest number of physical tests, three tests in total (Table 4.3). No strong correlation was found for boys; however, the highest correlation was found between efforts of HRS and relative force (r=0.66) (Table 4.3). In contrast, girls had six strong correlations, where the highest correlation was found between efforts of sprinting and relative force (r=0.79) (Table 4.3).

Table 4.3: Correlation between percentage change in physical fitness and average training load per period.

	10 m	30 m	CoD	CMJ	Total Force	Total Power	Relative Force	Relative Power	YYIR-1
Boys	(n=14)	(n=14)	(n=14)	(n=14)	(n=10)	(n=13)	(n=10)	(n=13)	(n=9)
Girls	(n=11)	(n=11)	(n=10)	(n=12)	(n=9)	(n=11)	(n=9)	(n=11)	(n=3)
Duration (min)									
Boys	-0.62*	-0.35	0.29	0.14	-0.14	0.34	-0.06	0.46	-0.19
Girls	0.50	0.71*	0.68*	-0.02	-0.11	0.28	0.08	0.34	---
Total Distance (m)									
Boys	0.01	-0.04	-0.38	-0.27	0.53	0.52	0.30	0.27	-0.07
Girls	0.07	-0.01	-0.08	0.22	0.64	0.40	0.66	0.34	---
Total PL (au)									
Boys	0.08	0.01	-0.48	-0.23	0.55	0.48	0.39	0.28	-0.04
Girls	-0.12	-0.25	-0.16	0.09	0.67*	0.37	0.59	0.26	---
HSR Distance (m)									
Boys	-0.02	-0.03	-0.08	-0.20	0.34	0.50	0.10	0.25	-0.07
Girls	0.04	-0.12	-0.11	0.25	0.76*	0.45	0.71*	0.34	---
Sprinting Distance (m)									
Boys	0.07	0.01	0.16	-0.31	0.12	0.27	-0.09	0.08	-0.18
Girls	0.12	-0.06	-0.14	0.03	0.59	0.63*	0.77*	0.61*	---
LRS Distance (m)									
Boys	0.07	-0.02	-0.38	-0.04	0.60	0.61*	0.50	0.44	-0.02
Girls	-0.18	-0.46	-0.40	-0.02	0.46	0.48	0.41	0.37	---
MRS Distance (m)									
Boys	0.06	-0.06	-0.39	-0.18	0.53	0.48	0.41	0.31	0.05
Girls	-0.17	-0.48	-0.42	-0.08	0.41	0.51	0.40	0.43	---
HRS Distance (m)									
Boys	0.09	-0.11	-0.58*	-0.10	0.58	0.49	0.53	0.36	0.23
Girls	-0.22	-0.50	-0.45	-0.19	0.20	0.48	0.29	0.47	---
HIE (n)									
Boys	0.16	0.03	-0.59*	-0.05	0.64*	0.39	0.55	0.26	0.13
Girls	-0.22	-0.42	-0.43	0.14	0.36	-0.04	0.21	-0.14	---
Efforts of HSR (13-18 km/h) (n)									
Boys	-0.06	-0.07	0.07	-0.12	0.38	0.56*	0.18	0.34	0.06
Girls	0.06	0.10	-0.12	0.27	0.73*	0.46	0.69*	0.35	---
Efforts of Sprinting (n)									
Boys	0.02	-0.02	0.17	-0.23	0.15	0.34	-0.06	0.13	-0.16
Girls	0.22	0.02	-0.10	0.09	0.59	0.66*	0.79*	0.65*	---
Efforts of LRS (n)									
Boys	0.06	-0.03	-0.41	0.05	0.62	0.65*	0.56	0.50	-0.02
Girls	-0.22	-0.50	-0.42	-0.03	0.40	0.43	0.33	0.32	---
Efforts MRS (n)									
Boys	0.05	-0.11	-0.51	-0.03	0.60	0.60*	0.55	0.45	0.19
Girls	-0.20	-0.50	-0.45	-0.14	0.29	0.51	0.34	0.46	---
Efforts of HRS (n)									
Boys	0.08	-0.18	-0.65*	-0.02	0.64*	0.55	0.66*	0.45	0.30
Girls	-0.15	-0.43	-0.39	-0.17	0.19	0.55	0.32	0.55	---
sRPE-TL (au)									
Boys	-0.34	-0.08	0.26	0.04	0.07	-0.25	-0.16	-0.35	-0.64
	(n=12)	(n=12)	(n=12)	(n=12)	(n=9)	(n=11)	(n=9)	(n=11)	(n=8)
Girls	-0.32	-0.39	-0.26	-0.18	0.33	0.13	0.35	0.13	---

au – arbitrary unit; HIE – High-Intensity Efforts; HSR – High-Speed Running; sRPE-TL – session rating of perceived exertion training load; LRS – low relative sprinting; MRS – medium relative sprinting; HRS – high relative sprinting; PL – PlayerLoad.

5. Discussion

The purpose of this study was to investigate the relationship between training load measures and development of physical fitness for football players during adolescence. Here, the results from this study will be discussed and compared to other studies to get a better understanding of the topic. In addition, to the main research question, sub-research questions will be discussed to address other aspects related to the topic.

Results showed that several training load measures correlated with the percentage change in physical fitness, which indicates a relationship between these measures (Table 4.3). Here, boys had eleven significant correlations, all moderately, whereas girls had thirteen significant correlations with six of them correlating strongly (Table 4.3). For physical fitness, boys performed significantly better compared to girls in six out of nine tests during pre-testing, here girls had similar results for YYIR-1, total force- and total power production (Table 4.1). At post-testing, boys performed significantly better in eight tests compared to girls (Table 4.1). Furthermore, boys tended to increase their percentage change in physical fitness more compared to girls, except for the 10-m sprint, however only three of the physical tests were of significant difference. (Figures 4.1 a-k). These results show that there is a difference in physical fitness and development between sexes during adolescence. Lastly, duration, TD, PL, and HSR distance were similar for both sexes, however, boys had higher; sprinting distance, sprinting efforts, and HIE, still, the relative measures were close to identical (Table 4.2). These results show differences in absolute training load measures, but similarities in relative training load measures between sexes during adolescence.

5.1 Development in Physical Fitness and Anthropometrics

For the anthropometrical measures, height and weight, there were no significant differences between sexes, neither at pre- or post-testing (Table 4.1). Additionally, both sexes increased anthropometrical measures over one year (Table 4.1). Despite not being significantly different, girls tended to be taller and heavier compared to boys during pre-testing. This agrees with previous studies saying that girls reach their PHV and peak gain in mass earlier than boys (Corso, 2018, p. 152; Malina & Koziel, 2014a, p. 426; 2014b, p. 1378; Mirwald et al., 2002, p. 690). As boys had a significantly greater percentage change in anthropometrics, height and weight, the differences between sexes were smaller during post-testing (Figures 4.1a & b; Table 4.1). This is also in agreement with previous studies, as boys reach their PHV and peak gain in mass later compared to girls (Corso, 2018, p. 152; Malina & Koziel, 2014a, p. 426; 2014b, p. 1378; Mirwald et al., 2002, p. 690). The relative changes in this study were somewhat greater for both weight and height compared to the study of Williams et al. (2011, p. 269), when comparing changes occurring from mid-U15 to mid-U16, which would be the most comparable groups for this age group. However, as this study has collected and calculated an average of change for several subjects in different ages this might affect the results. Whereas William et al. (2011, p. 270) used a cross-sectional design, where the measurements were made for different subjects within the same age group.

For sprinting, 10-m and 30-m, and CoD boys performed better during both pre- and post-testing compared to girls (Figure 4.1). For 10-m and 30-m sprinting, these results were slightly worse compared to Gundersen et al. (2020, p. 259) and William et al. (2011, p. 267) who tested male football players of the same age. Then again, these results might be affected by a different start set-up as they started 60 cm and 100 cm behind the photocells, compared to 50 cm in this project. Starting further away from the starting photocells has been proven to give better results for sprint tests (Haugen et al., 2015, p. 1056). However, the results were closer to the players from the study of le Gall et al. (2010, p. 92), and slightly better than the study of Malina et al. (2004, p. 558) making these subjects seem similar with other studies. Furthermore, both girls and boys improved from pre- to post-testing, whereas the relative changes in sprinting for boys were similar to the changes in the study of Williams et al. (2011, p. 271) and Hammami et al. (2013, p. 592) for athletes of the same age group. However, when comparing these results to the control group of Hammami et al. (2013, p. 592), the percentage of change for 10-m sprinting was better for this study. Furthermore, this might indicate that there is an additional benefit with a higher training load for improving physical fitness during adolescence.

Boys performed better in CMJ, relative force, and relative power at both pre- and post-testing compared to girls (Table 4.1). Here, in contrast to 10-m, boys jumped higher compared to the study of Gundersen et al. (2020, p. 259) and Malina et al. (2004, p. 558). Other studies have shown jump performances much greater compared to this study (le Gall, 2010, p. 92; Williams et al., 2011, p. 267). However, these studies used jump mats, rather than a force platform, making the comparison hard as jump height is measured differently (Nielsen et al., 2019, p. 9). The percentage development in CMJ for boys was similar to the study of Hammami et al. (2013, p. 592). Furthermore, only boys improved significantly from pre- to post-testing, for these three tests (Figure 4.1). However, as these tests reflect the relative force and relative power production in the lower limbs, they were expected to have similarities in change (Paul & Nassis, 2015, p. 1755; Raastad, 2010, p. 225). When comparing the total force- and total power production to the relative force- and relative power production, boys will benefit in the relative measures, as they gain more FFM during adolescence compared to girls who gain more FM (Corso, 2018, p. 152). Fewer studies have analyzed the change in relative force- and relative power production, however, we could assume that the changes here would follow the same patterns as CMJ because it tests similar abilities. As the greatest change in jumping performance occurred from U15 to U16 in the study performed by Williams et al. (2011, p. 273), they speculate if these changes might be linked to the peak gain in mass for boys, which also could explain the changes seen for boys in this study.

Total force production was similar between sexes, both at pre- and post-testing (Table 4.1). Also, they both improved from pre- to post-testing (Table 4.1). Total force- and total power production were higher in this study compared to Gundersen et al. (2020, p. 259). The earlier maturation for girls might offer an explaination for the similarities between sexes in total force- and total power production during pre-testing (Malina & Koziel, 2014a, p. 426; 2014b, p. 1378) (Table 4.1). The earlier maturation will benefit girls as they have an earlier increase in mass (Corso, 2018, p. 152). Despite the greatest share of mass being FM, there is also an increase in FFM to produce force and power for girls (Corso, 2018, p. 152). As boys typically have a greater increase in FFM following PHV compared to girls, boys are expected to improve more for total force- and total power production compared to girls (Corso, 2018, p. 152). Boys gained 6 kg of body mass compared to girls who gained close to 2 kg (table 4.1), this gives boys an advantage in improving total force- and total power production. In agreement with the literature, boys had a significantly greater percentage change in total force- and total power production compared to the girls (Figures 4.1 g-h). The greater percentage change in total power resulted in differences between sexes for total power production (Table 4.1). As a result of the greater percentage change in weight for boys, the percentage change in relative force- and relative power production were similar between the sexes (Figure 4.1 i-j).

Furthermore, abilities discussed as important to perform well in CoD are coordination and leg strength (Sheppard & Young, 2006, p. 923). Considering the greater percentage change in total force- and total power production among boys compared to girls, it would be assumed that these changes would reflect the changes in CoD as well. However, Sheppard & Young (2006, p. 923) only found weak to moderate correlations between leg strength and CoD. As boys still had similar percentage change in CoD (Figure 4.1 e) these findings support Sheppard & Young (2006, p. 923) that the increase in CoD performance might come from other aspects than strength, highlighting the coordination aspect and the benefit of working specifically to increase this skill.

Lastly, running distance during YYIR-1 was similar during pre-testing (Table 4.1). However, boys increased their distance significantly, whereas girls decreased their distance, not significantly, from pre- to post-testing (Table 4.1). Additionally, as boys had a significanlty greater percentage change in performance compared to girls (Figure 4.1k), this led to a difference between sexes at post-testing (Table 4.1). Here, the sample size was small for girls, which might affect the results. At pre-testing, boys ran shorter compared to other studies (Grendstad et al., 2020, p. 259; Malina et al., 2004, p. 558). Whereas this study and Grenstad et al. (2020, p. 258) performed the running test inside a sports hall, Malina et al. (2004, p. 556) performed their YYIR-1 outside on a football field, which might be favorable when measuring football players. Another factor that might help explain the big difference compared to the results of Malina et al. (2004, p. 558) is the level of players, as he recruited players from the top level in Portugal at this age. Boys were expected to improve more than girls during adolescence as a result of maturation (Boyadjiev & Taralov, 2000, p. 201). Conversly, the decreased performance among girls could potentially be a result of the increased body mass (Table 4.1), without a further improvement in running performance, which could be observed for girls around this age (Greier et al., 2019, p. 264). The relative change in performance was not as good for the boys compared to another study with age-matched football players, though it must be stated that these players were elite players in their age with much higher training volume (Hammami et al., 2013, p. 594). However, when comparing the percentage change to the control group of Hammami et al. (2013, p. 594), the change in YYIR-1 was much higher for the boys in this project. This might indicate that a higher training load leads to better improvements in physical fitness during adolescence.

To summarize, boys tend to perform better for the relative tests, tests where you either need to carry your body weight or make the results relative to body weight. This might be explained by the differences in increase of mass, typically boys increase their FFM, whereas girls typically increase their FM as a result of maturation (Corso, 2018, p. 152). As boys increased performance significantly for eight out of nine tests, whereas girls only improved significantly in four out of nine tests from pre- to post-testing, this shows that boys have a greater physical fitness development during adolescence. Additionally, boys tended to have a greater percentage change in performance for the tests, except for the 10-m sprint, despite only total force, total power and YYIR-1 showed statistically improvements for percentage change (Figures 4.1c-k)

5.2 Differences in Training Load

As there was no difference in duration between sexes (table 4.2), the measures are therefore not affected by a longer compared to a shorter duration, but rather the work performed during training. Training loads were similar between both sexes for most of the measures (table 4.2). However, boys covered longer distances sprinting simultaneously as having more efforts of sprinting and HIE (table 4.2). This is in agreement with other literature where the main differences between sexes are in the higher velocities (McFadden et al., 2020, p. 973). As the HIE also has a set threshold, this might be harder for girls to overcome compared to boys, as boys have a higher relative strength (table 4.1). Relative strength might affect HIE as players must control and accelerate/decelerate their body weight. Boys had a higher maximal speed compared to girls, thus, it will take less effort for boys to reach the threshold for sprinting compared to girls. However, when comparing relative sprinting distances and relative sprinting efforts, measures are similar (table 4.2). This supports the arguments for using relative thresholds when comparing training load between individuals and sexes (Gabbett, 2015, p. 3356).

In comparison with sub-elite male U15 football players the training load seemed to be slightly lower in this project (Teixeira et al., 2021, p. 5). Conversely, the distance covered in HSR seems to be higher in this study, however as Teixeria et al. (2021, p. 4) had a slightly higher threshold for HSR, which then will affect the distance covered in this measure making them difficult to compare. Additionally, Teixeria et al. (2021, p. 4) excluded training load from matches, which would further increase their weekly training volume if this would have been included, resulting in an even greater difference. The internal training load was also higher for Teixeira et al. (2021, p. 5), however, as our study did not have any inclusion criteria for sRPE this measure has few responses resulting in a relatively low value. If the response rate would have been higher, this would increase the value of the sRPE-TL.

5.3 Relationship between Training Load and Physical Fitness

Boys correlated moderately negatively for duration with 10-m sprint, whereas girls correlated strongly positively for duration with 30-m sprint and moderately positively with CoD (table 4.3). As a higher training load is associated with better performance for physical fitness tests in boys (Rice et al., 2022, p. 16), it would be assumed that a longer duration would correlate with a better improvement, negatively in this case, compared to a shorter duration. Therefore, the correlation found for boys was expected, on the other hand, the correlation for girls indicates that longer duration, a higher training volume, leads to less improved performance for 30 m sprint and CoD. These results might indicate a difference in training content. To increase in performance for these tests of high intensity, it would also be assumed that training should be of higher intensity to stimulate these changes. Previously, duration has been correlated to be possibly trivial and possibly small for changes in 5-m and 15-m sprint performance for junior players (Gil-Rey et al., 2015, p. 2130). As this study shows both positive and negative correlations for duration and sprinting performance, this might indicate that duration might not make a big difference, here the content during training might be of more interest. Still, no other measure of training load correlated significantly with duration for this study (Table 4.3). Additionally, change in CoD correlated negatively moderately with distance covered in HRS, efforts of HRS, and HIE, all correlations for boys (Table 4.3). In contrast to previously discussed correlations where girls and boys correlated with opposite values, girls have similar correlations despite not being statistically significant. Wrigley et al. (2014, p. 1092) found a better improvement in agility for the academy players, who had a higher training load, compared to the non-academy players. However, they do not state what training load measure that makes the difference. Here, the external measures correlating with CoD, are measures at their maximal velocities and HIE for boys. Despite not reaching near their maximal velocities during the CoD test, measures of HRS seem to be of importance, maybe as a result of similarities in rapid and powerful movements. Especially the HIE might be similar to the abilities tested during the CoD which again supports the principle of training specific as mentioned by Lesinski et al. (2020, p. 1925) and Thieschafer & Busch (2022, p. 18).

For girls, total power and relative power correlated moderately positively with the sprinting distance and sprinting efforts, which reflects the similarities in creating high power in rapid muscle contractions (Table 4.3) (Raastad et al., 2010, p. 13). For boys, total power correlated moderately positively with; distance covered in LRS, efforts of HSR, efforts of LRS, and efforts of MRS, which is more surprising compared to correlations for girls (Table 4.3). Here, maturation might be a confounding factor as power is highly related to muscle strength and muscle mass (Wrigley et al., 2014, p. 1092). As the average age of boys were 14.4 years at pre-testing (table 3.1), they are reaching their peak gain of mass by post-testing which will affect the ability to produce both force and power positively (Corso, 2018, p. 152). However, the external measures correlating with total power are of moderately high velocities, not the maximal velocities. The moderately high velocities will require similar abilities to produce power during rapid contraction, although it was be expected to be stronger correlations for the highest velocities also for boys, not only for girls.

Total force correlated moderately positively with PL and strongly positively with both HSR distance and efforts of HSR for girls, whereas total force had moderate correlations with HIE and efforts of HRS for boys (Table 4.3). During the HIE players must control and produce high forces when performing movements which could explain the correlation with the increase in force. However, the efforts of HRS would be expected to be more related to power rather than force, as force is more dependent on movements with slower muscle contractions, rather than fast muscle contractions seen with sprinting. Then again, players also produce high forces during sprinting, agreeing with the correlation between increase in force and HSR for boys. Furthermore, leg strength has previously been shown to correlate with sprinting performance which might support the correlation between efforts of HRS and total force (Lockie et al., 2015, p. 71). Correlation is not the same as causality, therefore, the results do not detect either if the external training load leads to a change in physical fitness or if the change in physical fitness leads to an increase in external training load, it could be speculated that with the increase in total force, it would be easier for boys to perform more HIE or more sprints. As PL is a measure of the accelerations in all three planes (Luteberget et al., 2018, p. 468), the correlation between

PL and change in force for girls will be supported with similar arguments as HIE, despite not having the same threshold for accelerations. Relative force has similarities in correlations with total force and total power which also will result in similarities in arguments to support these correlations.

Total force, total power, and relative force were the tests that correlated significantly with the most external measures (Table 4.3). Here, total force and relative force often correlated with the same external measures, however, there were no tests that correlated statistically for both girls and boys which might indicate differences between sexes. With that said, they often had similar patterns which on the other hand might indicate similarities between the sexes. These differences might be a result of either a small sample size, or they might respond differently. However, it should be noted that these measures provide limited representations of a larger construct, as improvements in performance on these tests may also be influenced by factors beyond the scope of the measured training load.

Neither CMJ or YYIR-1 had any statistically significant correlations with the given training load measures (figure 4.3). Wrigley et al. (2014, p. 1092) found greater improvement in both CMJ and YYIR-2 when comparing academy players to non-academy players, however, they do not know what measures that led to the change in jumping performance. Development in YYIR-1 and CMJ might therefore not come from one specific measure or might be more as a result of maturation rather than training load.

Lastly, duration, TD, and PL often correlate with each other (McLaren et al., 2018, p. 651), therefore the measures correlating with duration should also correlate with TD and PL, however, this is not the case in this study. Here, TD and PL correlate strongly positively with each other for this study (not shown), which is also the reason for these measures to often have similar correlations with other tests (Figure 4.3).

5.4 Limitations

One limitation of this study could be the inclusion criteria for what percentage of training participation athletes needed to fulfill to be included. When excluding subjects with a lower percentage of participation, this will reduce the number of participations. However, there are different reasons to not participate in a training session. One of them is playing for an older age group. Here, players would be registered with a “fake” low training load which would affect the results. On the other hand, some players might regularly take part in fewer sessions. Then, data collection would have their realistic training load and would result in a higher number of participants. As this study did not control every single subject, criteria for participation were made to reduce the chance of unreliable data.

Furthermore, the three periods for data collection are meant to represent their yearly training load. However, one or several of the chosen periods might not be representative of their yearly training load, either giving higher or lower training loads than their usual training sessions. Then again, the periods are spread all over the year with intention to cover the different parts of a season.

Another limitation of this study is that there were no inclusion criteria for reporting their sRPE during their selected periods. Preferably, there would also be criteria for self-reported training load as this would give even more data, and reliable data, for their internal training load during football sessions along with sessions outside football. However, as so few reported their sRPE during their periods, an inclusion criterion would reduce the number of participants. Therefore, the data reported for the internal training load are much lower than expected and should be interpreted with caution. This might also indicate difficulty to collect reliable sRPE measures during adolescence.

For testing, one limitation is the lack of familiarization for the athletes. As some of the tests might be new for athletes, this might affect the results leading to a better improvement than expected (Vrbik et al., 2017, p. 281). Athletes might handle the tests better, and therefore perform better during post-testing, despite not having improved that much physically. Another limitation of the testing is the lack of a standardized order for all the physical tests. Results will be affected if an athlete experience fatigue in one test before completing another test when they performed these tests in another order during post-testing. It is not important that every single athlete perform tests in the same order, however, it would be preferred that athletes performed their tests in the same order for pre- and post-testing. However, this would make testing more time-consuming, which also could lead to less motivated athletes. As YYIR-1 testing was performed in different locations during pre- and post-testing for some athletes, this might affect the results to be either unrealistically high or reduced compared to their realistic improvement. The surface and surroundings of the locations might differ, making it either easier or harder to reach the similar distances.

Lastly, the small sample size will be a limitation of this study, especially for the results correlating percentage change in physical fitness with training load measures. As the subjects are in a period with rapid changes in physical fitness, the results will be affected by maturity. Here, the correlations are of a higher risk of showing random variation due to the small sample size.

It must be stated that this project has performed a correlation analysis, this does not state causality. Therefore, future studies should further investigate the relationship between training load measures and development in physical fitness. Here, the studies should be for a prolonged period with a larger sample size, where they also would be able to collect data when playing for the elderly or other teams. As a result of being able to monitor a more realistic training load, this would increase the sample size and include more athletes with less participation, as fewer would be excluded for not taking part in their regular team sessions. It would also be of interest to investigate how two similar groups would respond to different types of training, here training sessions could have been manipulated to give different stimuli of training load. Lastly, it would also be interesting to investigate how these changes in physical fitness, or differences in training load, would affect "performance" in football matches.

6. Practical Application

This study will give relevant information to coaches and people working with youth football players. Firstly, test results and changes in physical fitness over one year can be used to get a better understanding of expected results and development during adolescence. Secondly, the study has measured training load measures for both sexes for several weeks throughout a season. These measures can be used in comparison to their training load, further, this can lead to modifications of their training sessions. Thirdly, the correlations between training load measures and changes in physical fitness will give a better understanding of the relationship between training load measures and development in physical fitness. This relationship will help coaches to better understand what type of training would lead to what type of development in physical fitness characteristics. Here, training sessions or training exercises could be modified to better reach wanted development in physical fitness characteristics – which further might affect match performance. When interpreting findings from this study, a higher training load would lead to greater development, however, this must be implicated with caution due to the increased risk of injuries associated with a higher training load (Gabbett, 2016, p. 2). Lastly, as this study has a low response rate for sRPE this must be used with caution for athletes during adolescence. If implicating reporting of sRPE, this should be monitored by the coaches and completed after sessions to ensure better reliability for the internal training load.

7. Conclusion

The purpose of this study was to further investigate the relationship between training load measures and development in physical fitness for football players during adolescence. Additionally, the study indeed to get a better understanding of changes in physical fitness over one year, along with training load measures spread throughout a year.

Firstly, several training load measures correlated with the change in physical fitness characteristics for both sexes, indicating a relationship between training load and development in physical fitness. With the results from this study, it seems like a higher training load leads to a greater development in physical fitness. However, there are exceptions, girls seem to have a positively correlation for sprinting and CoD with duration, in contrast to boys where the correction for duration and sprinting was negatively. Here, training contact might explain the differences. Overall, the force and power tests were to be the tests with the most correlations with the training load measures, supporting the idea that a higher training load leads to greater development.

Secondly, boys performed significantly better compared to girls in six out of nine tests during pre-testing. Furthermore, as boys had significantly greater percentage change in performance in three physical tests, they increased to performing significantly better in eight out of nine tests during post-testing. Still, girls increased performance from pre- to post-testing in four physical tests, whereas boys increased performance for all nine tests. In total, these results shows that boys develop more compared to girls during adolescence.

Thirdly, most of the training load measures were similar for boys and girls. The measures with significant differences were sprinting distance, sprinting efforts, and HIE, which might indicate that the main differences for training load appear at the highest velocities and during efforts of high intensity. As these are measured with absolute thresholds, this is beneficial for boys as they have a greater maximal velocity and perform better during physical testing. However, when comparing the relative measures, the distances covered, and efforts made are close to identical. Relative measures might therefore be a fairer comparison, especially when comparing sexes or athletes during adolescence as there are large differences in physical fitness.

References

Algroy, E., Grendstad, H., Riiser, A., Nybakken, T., Saeterbakken, A. H., Andersen, V., & Gundersen, H. S. (2021). Motion Analysis of Match Play in U14 Male Soccer Players and the Influence of Position, Competitive Level and Contextual Variables. *Int J Environ Res Public Health*, *18*(14). https://doi.org/10.3390/ijerph18147287

Andersen, T. E., Tenga, A., Engebretsen, L., & Bahr, R. (2004). Video analysis of injuries and incidents in Norwegian professional football. *Br J Sports Med*, *38*(5), 626-631. https://doi.org/10.1136/bjsm.2003.007955

Armstrong, N., & Mechelen, M. (2017). *Oxford Textbook of Children´s Sport and Exercise Medicine* (3. ed.). Bell & Bain Ltd., Glasgow.

Armstrong, N., & Welsman, J. (2019). Sex-Specific Longitudinal Modeling of Youth Peak Oxygen Uptake. *Pediatr Exerc Sci*, *31*(2), 204-212. https://doi.org/10.1123/pes.2018-0175

Bangsbo, J., Iaia, F. M., & Krustrup, P. (2007). Metabolic response and fatigue in soccer. *Int J Sports Physiol Perform*, *2*(2), 111-127. https://doi.org/10.1123/ijspp.2.2.111

Bangsbo, J., Iaia, F. M., & Krustrup, P. (2008). The Yo-Yo intermittent recovery test : a useful tool for evaluation of physical performance in intermittent sports. *Sports Med*, *38*(1), 37-51. https://doi.org/10.2165/00007256-200838010-00004

Barnes, C., Archer, D. T., Hogg, B., Bush, M., & Bradley, P. S. (2014). The evolution of physical and technical performance parameters in the English Premier League. *Int J Sports Med*, *35*(13), 1095-1100. https://doi.org/10.1055/s-0034-1375695

Baxter-Jones, A. D., & Maffulli, N. (2003). Endurance in young athletes: it can be trained. *Br J Sports Med*, *37*(2), 96-97. https://doi.org/10.1136/bjsm.37.2.96

Beunen, G. P., Rogol, A. D., & Malina, R. M. (2006). Indicators of biological maturation and secular changes in biological maturation. *Food Nutr Bull*, *27*(4 Suppl Growth Standard), S244-256. https://doi.org/10.1177/15648265060274s508

Bidaurrazaga-Letona, I., Carvalho, H. M., Lekue, J. A., Santos-Concejero, J., Figueiredo, A. J., & Gil, S. M. (2015). Longitudinal field test assessment in a Basque soccer youth academy: a multilevel modeling framework to partition effects of maturation. *Int J Sports Med*, *36*(3), 234-240. https://doi.org/10.1055/s-0034-1385881

Bloomfield, J., Polman, R., & O'Donoghue, P. (2007). Physical Demands of Different Positions in FA Premier League Soccer. *J Sports Sci Med*, *6*(1), 63-70. https://www.ncbi.nlm.nih.gov/pubmed/24149226

Bourdon, P. C., Cardinale, M., Murray, A., Gastin, P., Kellmann, M., Varley, M. C., Gabbett, T. J., Coutts, A. J., Burgess, D. J., Gregson, W., & Cable, N. T. (2017). Monitoring Athlete Training Loads: Consensus Statement. *Int J Sports Physiol Perform*, *12*(Suppl 2), S2161-S2170. https://doi.org/10.1123/IJSPP.2017-0208

Boyadjiev, N., & Taralov, Z. (2000). Red blood cell variables in highly trained pubescent athletes: a comparative analysis. *Br J Sports Med*, *34*(3), 200-204. https://doi.org/10.1136/bjsm.34.3.200

Buchheit, M., Mendez-Villanueva, A., Delhomel, G., Brughelli, M., & Ahmaidi, S. (2010). Improving repeated sprint ability in young elite soccer players: repeated shuttle sprints vs. explosive strength training. *J Strength Cond Res*, *24*(10), 2715-2722. https://doi.org/10.1519/JSC.0b013e3181bf0223

Buchheit, M., Mendez-Villanueva, A., Simpson, B. M., & Bourdon, P. C. (2010). Match running performance and fitness in youth soccer. *Int J Sports Med*, *31*(11), 818-825. https://doi.org/10.1055/s-0030-1262838

Carling, C. (2013). Interpreting physical performance in professional soccer match-play: should we be more pragmatic in our approach? *Sports Med*, *43*(8), 655-663. https://doi.org/10.1007/s40279-013-0055-8

Castagna, C., Impellizzeri, F., Cecchini, E., Rampinini, E., & Alvarez, J. C. (2009). Effects of intermittent-endurance fitness on match performance in young male soccer players. *J Strength Cond Res*, *23*(7), 1954-1959. https://doi.org/10.1519/JSC.0b013e3181b7f743

Castillo, D., Raya-Gonzalez, J., Manuel Clemente, F., & Yanci, J. (2020). The influence of youth soccer players' sprint performance on the different sided games' external load using GPS devices. *Res Sports Med*, *28*(2), 194-205. https://doi.org/10.1080/15438627.2019.1643726

Cometti, G., Maffiuletti, N. A., Pousson, M., Chatard, J. C., & Maffulli, N. (2001). Isokinetic strength and anaerobic power of elite, subelite and amateur French soccer players. *Int J Sports Med*, *22*(1), 45-51. https://doi.org/10.1055/s-2001-11331

Cormack, S. J., Newton, R. U., McGuigan, M. R., & Doyle, T. L. (2008). Reliability of measures obtained during single and repeated countermovement jumps. *Int J Sports Physiol Perform*, *3*(2), 131-144. https://doi.org/10.1123/ijspp.3.2.131

Corso, M. (2018). Developmental changes in the youth athlete: implications for movement, skills acquisition, performance and injuries. *J Can Chiropr Assoc*, *62*(3), 150-160. https://www.ncbi.nlm.nih.gov/pubmed/30662070

Cummins, C., Orr, R., O'Connor, H., & West, C. (2013). Global positioning systems (GPS) and microtechnology sensors in team sports: a systematic review. *Sports Med*, *43*(10), 1025-1042. https://doi.org/10.1007/s40279-013-0069-2

Deprez, D., Fransen, J., Lenoir, M., Philippaerts, R., & Vaeyens, R. (2015). The Yo-Yo intermittent recovery test level 1 is reliable in young high-level soccer players. *Biol Sport*, *32*(1), 65-70. https://doi.org/10.5604/20831862.1127284

Di Salvo, V., Benito, P. J., Calderon, F. J., Di Salvo, M., & Pigozzi, F. (2008). Activity profile of elite goalkeepers during football match-play. *J Sports Med Phys Fitness*, *48*(4), 443-446. https://www.ncbi.nlm.nih.gov/pubmed/18997646

Di Salvo, V., Gregson, W., Atkinson, G., Tordoff, P., & Drust, B. (2009). Analysis of high intensity activity in Premier League soccer. *Int J Sports Med*, *30*(3), 205-212. https://doi.org/10.1055/s-0028-1105950

Figueiredo, A. J., Goncalves, C. E., Coelho, E. S. M. J., & Malina, R. M. (2009). Youth soccer players, 11-14 years: maturity, size, function, skill and goal orientation. *Ann Hum Biol*, *36*(1), 60-73. https://doi.org/10.1080/03014460802570584

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., Doleshal, P., & Dodge, C. (2001). A new approach to monitoring exercise training. *J Strength Cond Res*, *15*(1), 109-115. https://www.ncbi.nlm.nih.gov/pubmed/11708692

Gabbett, T. J. (2002). Physiological characteristics of junior and senior rugby league players. *Br J Sports Med*, *36*(5), 334-339. https://doi.org/10.1136/bjsm.36.5.334

Gabbett, T. J. (2015). Use of Relative Speed Zones Increases the High-Speed Running Performed in Team Sport Match Play. *J Strength Cond Res*, *29*(12), 3353-3359. https://doi.org/10.1519/JSC.0000000000001016

Gabbett, T. J. (2016). The training—injury prevention paradox: should athletes be training smarter and harder? *British Journal of Sports Medicine*, *50*(5), 273-280. https://doi.org/10.1136/bjsports-2015-095788

Gil-Rey, E., Lezaun, A., & Los Arcos, A. (2015). Quantification of the perceived training load and its relationship with changes in physical fitness performance in junior soccer players. *J Sports Sci*, *33*(20), 2125-2132. https://doi.org/10.1080/02640414.2015.1069385

Gjerset, A., Nilsson, J., Helge, J. W., & Enoksen, E. (2015). *Idrettens treningslære* (Vol. 2). Oslo: Gyldendal.

Greier, K., Drenowatz, C., Ruedl, G., Kirschner, W., Mitmannsgruber, P., & Greier, C. (2019). Physical Fitness across 11-to 17-Year-Old Adolescents: A Cross-Sectional Study in 2267 Austrian Middle-and High-School Students. *Advances in Physical Education*, *09*. https://doi.org/10.4236/ape.2019.94018

Grendstad, H., Nilsen, A. K., Rygh, C. B., Hafstad, A., Kristoffersen, M., Iversen, V. V., Nybakken, T., Vestbostad, M., Algroy, E. A., Sandbakk, O., & Gundersen, H. (2020). Physical capacity, not skeletal maturity, distinguishes competitive levels in male Norwegian U14 soccer players. *Scand J Med Sci Sports*, *30*(2), 254-263. https://doi.org/10.1111/sms.13572

Hammami, M., Negra, Y., Shephard, R. J., & Chelly, M. S. (2017). Effects of leg contrast strength training on sprint, agility and repeated change of direction performance in male soccer players. *J Sports Med Phys Fitness*, *57*(11), 1424-1431. https://doi.org/10.23736/S0022-4707.17.06951-1

Hammami, M. A., Ben Abderrahmane, A., Nebigh, A., Le Moal, E., Ben Ounis, O., Tabka, Z., & Zouhal, H. (2013). Effects of a soccer season on anthropometric characteristics and physical fitness in elite young soccer players. *J Sports Sci*, *31*(6), 589-596. https://doi.org/10.1080/02640414.2012.746721

Haugen, T., Tonnessen, E., & Seiler, S. (2015). Correction Factors for Photocell Sprint Timing With Flying Start. *Int J Sports Physiol Perform*, *10*(8), 1055-1057. https://doi.org/10.1123/ijspp.2014-0415

Heishman, A., Daub, B., Miller, R., Freitas, E., Frantz, B., & Bemben, M. (2018). Countermovement Jump Reliability Performed With and Without an Arm Swing in NCAA Division 1 Intercollegiate Basketball Players. *Journal of Strength and Conditioning Research*, *34*, 1. https://doi.org/10.1519/JSC.0000000000002812

Impellizzeri, F. M., Marcora, S. M., & Coutts, A. J. (2019). Internal and External Training Load: 15 Years On. *Int J Sports Physiol Perform*, *14*(2), 270-273. https://doi.org/10.1123/ijspp.2018-0935

Impellizzeri, F. M., Rampinini, E., Coutts, A. J., Sassi, A., & Marcora, S. M. (2004). Use of RPE-based training load in soccer. *Med Sci Sports Exerc*, *36*(6), 1042-1047. https://doi.org/10.1249/01.mss.0000128199.23901.2f

Kelly, S. J., Watsford, M. L., Austin, D. J., Spurrs, R. W., Pine, M. J., & Rennie, M. J. (2017). Differences in Physical Capacity Between Junior and Senior Australian Footballers. *J Strength Cond Res*, *31*(11), 3059-3066. https://doi.org/10.1519/JSC.0000000000001720

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., Pedersen, P. K., & Bangsbo, J. (2003). The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Med Sci Sports Exerc*, *35*(4), 697-705. https://doi.org/10.1249/01.MSS.0000058441.94520.32

Landgraff, H. W. (2020). *Cardiorespiratory, hematological and body composition changes in maturing girls and boys with different training backgrounds* Norwegian School of Sport Sciences].

le Gall, F., Carling, C., Williams, M., & Reilly, T. (2010). Anthropometric and fitness characteristics of international, professional and amateur male graduate soccer players from an elite youth academy. *J Sci Med Sport*, *13*(1), 90-95. https://doi.org/10.1016/j.jsams.2008.07.004

Lesinski, M., Herz, M., Schmelcher, A., & Granacher, U. (2020). Effects of Resistance Training on Physical Fitness in Healthy Children and Adolescents: An Umbrella Review. *Sports Medicine*, *50*(11), 1901-1928. https://doi.org/10.1007/s40279-020-01327-3

Liebermann, D. G., & Katz, L. (2003). On the assessment of lower-limb muscular power capability. *Isokinetics and Exercise Science*, *11*, 87-94. https://doi.org/10.3233/IES-2003-0106

Lloyd, R. S., Oliver, J. L., Radnor, J. M., Rhodes, B. C., Faigenbaum, A. D., & Myer, G. D. (2015). Relationships between functional movement screen scores, maturation and physical performance in young soccer players. *J Sports Sci*, *33*(1), 11-19. https://doi.org/10.1080/02640414.2014.918642

Lockie, R. G., Jalilvand, F., Callaghan, S. J., Jeffriess, M. D., & Murphy, A. J. (2015). Interaction Between Leg Muscle Performance and Sprint Acceleration Kinematics. *J Hum Kinet*, *49*, 65-74. https://doi.org/10.1515/hukin-2015-0109

Lockie, R. G., Murphy, A. J., Schultz, A. B., Knight, T. J., & Janse de Jonge, X. A. (2012). The effects of different speed training protocols on sprint acceleration kinematics and muscle strength and power in field sport athletes. *J Strength Cond Res*, *26*(6), 1539-1550. https://doi.org/10.1519/JSC.0b013e318234e8a0

Lopez-Segovia, M., Pareja-Blanco, F., Jimenez-Reyes, P., & Gonzalez-Badillo, J. J. (2015). Determinant factors of repeat sprint sequences in young soccer players. *Int J Sports Med*, *36*(2), 130-136. https://doi.org/10.1055/s-0034-1385880

Loturco, I., Jeffreys, I., Abad, C. C. C., Kobal, R., Zanetti, V., Pereira, L. A., & Nimphius, S. (2020). Change-of-direction, speed and jump performance in soccer players: a comparison across different age-categories. *J Sports Sci*, *38*(11-12), 1279-1285. https://doi.org/10.1080/02640414.2019.1574276

Loturco, I., Kobal, R., Maldonado, T., Piazzi, A. F., Bottino, A., Kitamura, K., Abad, C. C. C., Pereira, L. A., & Nakamura, F. Y. (2017). Jump Squat is More Related to Sprinting and Jumping Abilities than Olympic Push Press. *Int J Sports Med*, *38*(8), 604-612. https://doi.org/10.1055/s-0035-1565201

Luteberget, L. S., Holme, B. R., & Spencer, M. (2018). Reliability of Wearable Inertial Measurement Units to Measure Physical Activity in Team Handball. *Int J Sports Physiol Perform*, *13*(4), 467-473. https://doi.org/10.1123/ijspp.2017-0036

Malina, R. M., Eisenmann, J. C., Cumming, S. P., Ribeiro, B., & Aroso, J. (2004). Maturity-associated variation in the growth and functional capacities of youth football (soccer) players 13-15 years. *Eur J Appl Physiol*, *91*(5-6), 555-562. https://doi.org/10.1007/s00421-003-0995-z

Malina, R. M., & Koziel, S. M. (2014a). Validation of maturity offset in a longitudinal sample of Polish boys. *J Sports Sci*, *32*(5), 424-437. https://doi.org/10.1080/02640414.2013.828850

Malina, R. M., & Koziel, S. M. (2014b). Validation of maturity offset in a longitudinal sample of Polish girls. *J Sports Sci*, *32*(14), 1374-1382. https://doi.org/10.1080/02640414.2014.889846

Malone, J. J., Lovell, R., Varley, M. C., & Coutts, A. J. (2017). Unpacking the Black Box: Applications and Considerations for Using GPS Devices in Sport. *Int J Sports Physiol Perform*, *12*(Suppl 2), S218-S226. https://doi.org/10.1123/ijspp.2016-0236

McFadden, B. A., Walker, A. J., Bozzini, B. N., Sanders, D. J., & Arent, S. M. (2020). Comparison of Internal and External Training Loads in Male and Female Collegiate Soccer Players During Practices vs. Games. *The Journal of Strength & Conditioning Research*, *34*(4), 969-974. https://doi.org/10.1519/jsc.0000000000003485

McLaren, S. J., Macpherson, T. W., Coutts, A. J., Hurst, C., Spears, I. R., & Weston, M. (2018). The Relationships Between Internal and External Measures of Training Load and Intensity in Team Sports: A Meta-Analysis. *Sports Med*, *48*(3), 641-658. https://doi.org/10.1007/s40279-017-0830-z

Miguel, M., Oliveira, R., Loureiro, N., Garcia-Rubio, J., & Ibanez, S. J. (2021). Load Measures in Training/Match Monitoring in Soccer: A Systematic Review. *Int J Environ Res Public Health*, *18*(5). https://doi.org/10.3390/ijerph18052721

Mirwald, R. L., Baxter-Jones, A. D., Bailey, D. A., & Beunen, G. P. (2002). An assessment of maturity from anthropometric measurements. *Med Sci Sports Exerc*, *34*(4), 689-694. https://doi.org/10.1097/00005768-200204000-00020

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci*, *21*(7), 519-528. https://doi.org/10.1080/0264041031000071182

Palucci Vieira, L. H., Carling, C., Barbieri, F. A., Aquino, R., & Santiago, P. R. P. (2019). Match Running Performance in Young Soccer Players: A Systematic Review. *Sports Med*, *49*(2), 289-318. https://doi.org/10.1007/s40279-018-01048-8

Paul, D. J., & Nassis, G. P. (2015). Testing strength and power in soccer players: the application of conventional and traditional methods of assessment. *J Strength Cond Res*, *29*(6), 1748-1758. https://doi.org/10.1519/JSC.0000000000000807

Rampinini, E., Alberti, G., Fiorenza, M., Riggio, M., Sassi, R., Borges, T. O., & Coutts, A. J. (2015). Accuracy of GPS devices for measuring high-intensity running in field-based team sports. *Int J Sports Med*, *36*(1), 49-53. https://doi.org/10.1055/s-0034-1385866

Rampinini, E., Coutts, A. J., Castagna, C., Sassi, R., & Impellizzeri, F. M. (2007). Variation in top level soccer match performance. *Int J Sports Med*, *28*(12), 1018-1024. https://doi.org/10.1055/s-2007-965158

Rave, G., Granacher, U., Boullosa, D., Hackney, A. C., & Zouhal, H. (2020). How to Use Global Positioning Systems (GPS) Data to Monitor Training Load in the "Real World" of Elite Soccer. *Front Physiol*, *11*, 944. https://doi.org/10.3389/fphys.2020.00944

Redden, J., Stokes, K., & Williams, S. (2018). Establishing the Reliability and Limits of Meaningful Change of Lower Limb Strength and Power Measures during Seated Leg Press in Elite Soccer Players. *J Sports Sci Med*, *17*(4), 539-546. https://www.ncbi.nlm.nih.gov/pubmed/30479521

Reilly, T., Williams, A. M., Nevill, A., & Franks, A. (2000). A multidisciplinary approach to talent identification in soccer. *J Sports Sci*, *18*(9), 695-702. https://doi.org/10.1080/02640410050120078

Requena, B., Gonzalez-Badillo, J. J., de Villareal, E. S., Ereline, J., Garcia, I., Gapeyeva, H., & Paasuke, M. (2009). Functional performance, maximal strength, and power characteristics in isometric and dynamic actions of lower extremities in soccer players. *J Strength Cond Res*, *23*(5), 1391-1401. https://doi.org/10.1519/JSC.0b013e3181a4e88e

Rice, J., Brownlee, T., McRobert, A., Ade, J., Drust, B., & Malone, J. (2022). The association between training load and physical development in professional male youth soccer players: a systematic review. *International Journal of Sports Science & Coaching*, *17*, 174795412210973. https://doi.org/10.1177/17479541221097388

Roe, G., Darrall-Jones, J., Black, C., Shaw, W., Till, K., & Jones, B. (2017). Validity of 10-HZ GPS and Timing Gates for Assessing Maximum Velocity in Professional Rugby Union Players. *Int J Sports Physiol Perform*, *12*(6), 836-839. https://doi.org/10.1123/ijspp.2016-0256

Rogol, A., Roemmich, J., & Clark, P. (2003). Growth at Puberty. *The Journal of adolescent health : official publication of the Society for Adolescent Medicine*, *31*, 192-200. https://doi.org/10.1016/S1054-139X(02)00485-8

Raastad, T., Paulsen, G., Refnes, P. E., Rønnestad, B. R., & Wisnes, A. R. (2010). *Styrketrening - i teori og praksis*. Oslo: Gyldendal.

Schoenfeld, B. J., & Snarr, R. L. (2021). *NSCA´s Essentials of Personal Training* (3 ed.).

Scott, M. T., Scott, T. J., & Kelly, V. G. (2016). The Validity and Reliability of Global Positioning Systems in Team Sport: A Brief Review. *J Strength Cond Res*, *30*(5), 1470-1490. https://doi.org/10.1519/JSC.0000000000001221

Scott, T. J., Black, C. R., Quinn, J., & Coutts, A. J. (2013). Validity and reliability of the session-RPE method for quantifying training in Australian football: a comparison of the CR10 and CR100 scales. *J Strength Cond Res*, *27*(1), 270-276. https://doi.org/10.1519/JSC.0b013e3182541d2e

Sheppard, J. M., & Young, W. B. (2006). Agility literature review: classifications, training and testing. *J Sports Sci*, *24*(9), 919-932. https://doi.org/10.1080/02640410500457109

Smalley, B., Bishop, C., & Maloney, S. J. (2021). "Small steps, or giant leaps?" Comparing game demands of U23, U18, and U16 English academy soccer and their associations with speed and endurance. *International Journal of Sports Science & Coaching*, *17*(1), 134-142. https://doi.org/10.1177/17479541211018771

Sporis, G., Jukic, I., Milanovic, L., & Vucetic, V. (2010). Reliability and factorial validity of agility tests for soccer players. *J Strength Cond Res*, *24*(3), 679-686. https://doi.org/10.1519/JSC.0b013e3181c4d324

Stewart, P. F., Turner, A. N., & Miller, S. C. (2014). Reliability, factorial validity, and interrelationships of five commonly used change of direction speed tests. *Scand J Med Sci Sports*, *24*(3), 500-506. https://doi.org/10.1111/sms.12019

Stolen, T., Chamari, K., Castagna, C., & Wisloff, U. (2005). Physiology of soccer: an update. *Sports Med*, *35*(6), 501-536. https://doi.org/10.2165/00007256-200535060-00004

Teixeira, J. E., Forte, P., Ferraz, R., Leal, M., Ribeiro, J., Silva, A. J., Barbosa, T. M., & Monteiro, A. M. (2021). Quantifying Sub-Elite Youth Football Weekly Training Load and Recovery Variation. *Applied Sciences-Basel*, *11*(11). https://doi.org/ARTN 4871

10.3390/app11114871

Thieschafer, L., & Busch, D. (2022). Development and trainability of agility in youth: A systematic scoping review. *Front Sports Act Living*, *4*, 952779. https://doi.org/10.3389/fspor.2022.952779

Toft Nielsen, E., Jorgensen, P. B., Mechlenburg, I., & Sorensen, H. (2019). Validation of an inertial measurement unit to determine countermovement jump height.

Asia Pac J Sports Med Arthrosc Rehabil Technol, *16*, 8-13. https://doi.org/10.1016/j.asmart.2018.09.002

Vahia, D., Kelly, A., Knapman, H., & Williams, C. A. (2019). Variation in the Correlation Between Heart Rate and Session Rating of Perceived Exertion-Based Estimations of Internal Training Load in Youth Soccer Players. *Pediatr Exerc Sci*, *31*(1), 91-98. https://doi.org/10.1123/pes.2018-0033

Varley, M. C., Gregson, W., McMillan, K., Bonanno, D., Stafford, K., Modonutti, M., & Di Salvo, V. (2017). Physical and technical performance of elite youth soccer players during international tournaments: influence of playing position and team success and opponent quality. *Science and Medicine in Football*, *1*(1), 18-29. https://doi.org/10.1080/02640414.2016.1230676

Viru, A., & Viru, M. (2000). Nature of training effects. In *Exercise and Sport Science* (pp. 67-95). Lippincott Wiliams & Wilkins.

Vrbik, I., Sporis, G., Stefan, L., Madic, D., Trajkovic, N., Valantine, I., & Milanovic, Z. (2017). The Influence of Familiarization on Physical Fitness Test Results in Primary School-Aged Children. *Pediatr Exerc Sci*, *29*(2), 278-284. https://doi.org/10.1123/pes.2016-0091

Williams, C. A., Oliver, J. L., & Faulkner, J. (2011). Seasonal monitoring of sprint and jump performance in a soccer youth academy. *Int J Sports Physiol Perform*, *6*(2), 264-275. https://doi.org/10.1123/ijspp.6.2.264

Wrigley, R. D., Drust, B., Stratton, G., Atkinson, G., & Gregson, W. (2014). Long-term soccer-specific training enhances the rate of physical development of academy soccer players independent of maturation status. *Int J Sports Med*, *35*(13), 1090-1094. https://doi.org/10.1055/s-0034-1375616

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Abbreviations

CMJ	Countermovement Jump
CoD	Change of Direction
FM	Fat Mass
FFM	Fat-Free Mass
GNSS	Global Navigation Satellite System
HIE	High-Intensity Efforts
HRS	High Relative Sprinting
HSR	High-Speed Running
IMU	Inertial Measuring Unit
LRS	Low Relative Sprinting
MRS	Medium Relative Sprinting
PL	PlayerLoad
RPE	Rate of Perceived Exertion
sRPE	Session Rate of Perceived Exertion
sRPE-TL	Session Rate of Perceived Exertion Training Load
RM	Repetition Maximum
SD	Standard Deviation
TD	Total Distance
TRIMP	Training Impulse
YYIR-1	Yo-Yo Intermittent Recovery Test 1

Appendix

I. Assessment of application, NIH Ethical Committee
II. Assessment of application, NSD
III. Informed consent form

Appendix I – Assessment of application, NIH Ethical Committee

Live Luteberget
Institutt for fysisk prestasjon

OSLO 23. juni 2021

Søknad – 191-170621 Utvikling av fysisk form, treningsbelastning, skader/sykdom og psykososiale elementer i ungdomsidretten

Vi viser til søknad, prosjektbeskrivelse, informasjonsskriv og innsendt melding til NSD

I henhold til retningslinjer for behandling av søknad til etisk komite for idrettsvitenskapelig forskning på mennesker, ble det i komiteens møte av 17. juni 2021 konkludert med følgende:

Vurdering

Komiteens oppfatning er at beskrivelsen gitt i søknadsskjemaet punkt 2.5 Begrunnelse for valg av data og metode, er noe mangelfullt når det gjelder valg av instrument for psykososiale elementer og ber om en fullstendig oversikt som beskriver spørreskjemaene og med nærmere begrunnelse for aktuelle skjemaers relevans for forskningsspørsmålene i prosjektet (slik de fysiske testene er spesifisert og beskrevet i samme punkt).

I informasjonsskrivet under «Hva innebærer det for deg å delta» opplyses det at deltakerne to ganger i året bla vil besvare et spørreskjema om «psykososiale elementer». Videre opplyses det at et utvalg av deltakerne vil bli trukket ut til å gjennomføre flere målinger, herunder besvare et spørreskjema «om følelser og oppfatninger om treningen». Komiteens vurdering er at beskrivelsen av spørreskjemaene bør utdypes i informasjonsskrivet for i sikre at både de foresatt og deltakerne forstår hvilke tema og type spørsmål som inngår i skjemaene før de ev samtykker. Komiteen mener videre at de foresatte bør gis mulighet til å se spørreskjemaene før de samtykker til at deres barn kan delta.

Videre vises det i søknaden til at fysiske tester og trening alltid innebærer en viss risiko for skader, men at skaderisikoen vurderes til ikke å være høyere ved deltakelsen i denne studien enn ved egen trening. Komiteen forutsetter at det etableres en form for screening før deltagelse og beredskap for håndtering av eventuelle skader under gjennomføring av testene.

I søknaden antas det en dropout på 30% i studien. Utvalgets alder tilsier at en del utøvere vil slutte med idretten i den 3 års perioden som prosjektet pågår. Videre vil innsendelse av skjema for skader/sykdom hver 14. dag og vurdering av egen treningsbelastningen på en periode på 2 uker 3 ganger i året sannsynligvis også påvirke dropout andelen, gitt utvalgets alder. Komiteen ber prosjektledelsen vurdere hvorvidt en dropout på 30 pst er realistisk for å sikre at prosjektet lar seg gjennomføre i lys av utvalgets alder og de data som skal samles inn.

NIH NORGES IDRETTSHØGSKOLE

Besøksadresse: Sognsveien 220, Oslo
Postadresse: Pb 4014 Ullevål Stadion, 0806 Oslo
Telefon: +47 23 26 20 00, postmottak@nih.no
www.nih.no

Komiteen anbefaler at det i informasjonsskrivet er to avkrysningsmuligheter når det gjelder samtykke; en for den delen av prosjektet hele utvalget skal delta i og en for den delen kun et utvalg skal delta i.

Vedtak

På bakgrunn av forelagte dokumentasjon finner komiteen at prosjektet er forsvarlig og at det kan gjennomføres innenfor rammene av anerkjente etiske forskningsetiske normer nedfelt i NIHs retningslinjer. Til vedtaket har komiteen lagt følgende forutsetning til grunn:

- *Vilkår fra NSD følges*
- *Det etableres en form for screening før inkludering samt en beredskap for håndtering av eventuelle skader under gjennomføring av testene*
- *En fullstendig oversikt som beskriver spørreskjemaene for psykososiale elementer med begrunnelse for hvorfor disse skjemaene er valgt sendes komiteen til orientering*
- *Justerte informasjonsskriv i tråd med komiteenes merknader sendes komiteen til orientering*
- *En vurdering av realismen i oppgitt dropout andel sendes komiteen til orientering*
- *Etterspurt informasjon sendes innen 20. august*

Komiteen gjør oppmerksom på at vedtaket er avgrenset i tråd med fremlagte dokumentasjon. Dersom det gjøres vesentlige endringer i prosjektet som kan ha betydning for deltakernes helse og sikkerhet, skal dette legges fram for komiteen før eventuelle endringer kan iverksettes.

Komiteen forutsetter videre at prosjektet gjennomføres på en forsvarlig måte i tråd med de til enhver tid gjeldende tiltak ifbm Covid-19 pandemien.

Med vennlig hilsen

Anne Marte Pensgaard

Professor Anne Marte Pensgaard
Leder, Etisk komite, Norges idrettshøgskole

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www.nih.no

Appendix II – Assessment of application, NSD

NSD NORSK SENTER FOR FORSKNINGSDATA

NSD sin vurdering

Prosjekttittel

Physical and psychosocial characteristics, injuries and illnesses, training load, and their influence for well-being and sport continuation among youth team sport athletes

Referansenummer

754002

Registrert

09.06.2021 av Live Steinnes Luteberget - livesl@nih.no

Behandlingsansvarlig institusjon

Norges idrettshøgskole / Institutt for fysisk prestasjonsevne

Prosjektansvarlig (vitenskapelig ansatt/veileder eller stipendiat)

Live S Luteberget, livesl@nih.no, tlf: 40043516

Felles behandlingsansvarlige institusjoner

Universitetet i Agder / Fakultet for helse- og idrettsvitenskap / Institutt for helse- og sykepleievitenskap

Type prosjekt

Forskerprosjekt

Prosjektperiode

01.08.2021 - 01.08.2026

Status

19.08.2021 - Vurdert

Vurdering (1)

19.08.2021 - Vurdert

Det er vår vurdering at behandlingen vil være i samsvar med personvernlovgivningen, så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet den dagens dato med vedlegg, samt i meldingsdialogen mellom innmelder og NSD. Behandlingen kan starte.

TYPE OPPLYSNINGER OG VARIGHET
Prosjektet vil behandle alminnelige personopplysninger og særlige kategorier av personopplysninger om helse og rasemessig eller etnisk opprinnelse frem til 0108.2026.

LOVLIG GRUNNLAG

Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 nr. 11 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse, som kan dokumenteres, og som den registrerte kan trekke tilbake.

For alminnelige personopplysninger vil lovlig grunnlag for behandlingen være den registrertes samtykke, jf. personvernforordningen art. 6 nr. 1 a.

For særlige kategorier av personopplysninger vil lovlig grunnlag for behandlingen være den registrertes uttrykkelige samtykke, jf. personvernforordningen art. 9 nr. 2 bokstav a, jf. personopplysningsloven § 10, jf. § 9 (2).

PERSONVERNPRINSIPPER
NSD vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen:
- om lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen
- formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke viderebehandles til nye uforenlige formål
- dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante og nødvendige for formålet med prosjektet
- lagringsbegrensning (art. 5.1 e), ved at personopplysningene ikke lagres lengre enn nødvendig for å oppfylle formålet.

DE REGISTRERTES RETTIGHETER
NSD vurderer at informasjonen om behandlingen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13.

Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18) og dataportabilitet (art. 20).

Vi minner om at hvis en registrert tar kontakt om sine rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned.

FØLG DIN INSTITUSJONS RETNINGSLINJER
NSD legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32).

Universitetet i Agder er felles behandlingsansvarlig institusjon. NSD legger til grunn at behandlingen oppfyller kravene til felles behandlingsansvar, jf. personvernforordningen art. 26.

Catapult Sports er databehandler i prosjektet. NSD legger til grunn at behandlingen oppfyller kravene til bruk av databehandler, jf. art 28 og 29.

Prosjektet innebærer overføring av pseudonyme personopplysninger ut av EU/EØS. Koblingsnøkkelen forblir ved NIH. Oppgitt behandlingsgrunnlag er art. 46. NSD legger til grunn at behandlingen oppfyller kravene til behandling av personopplysninger utenfor EU (personvernforordningen kapittel 5).

For å forsikre dere om at kravene oppfylles, må prosjektansvarlig følge interne retningslinjer/rådføre dere med behandlingsansvarlig institusjon.

MELD VESENTLIGE ENDRINGER
Dersom det skjer vesentlige endringer i behandlingen av personopplysninger, kan det være nødvendig å melde dette til NSD ved å oppdatere meldeskjemaet. Før du melder inn en endring, oppfordrer vi deg til å lese om hvilken type endringer det er nødvendig å melde:
https://www.nsd.no/personverntjenester/fylle-ut-meldeskjema-for-personopplysninger/melde-endringer-i-meldeskjema
Du må vente på svar fra NSD før endringen gjennomføres.

OPPFØLGING AV PROSJEKTET
NSD vil følge opp underveis (hvert annet år) og ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet/pågår i tråd med den behandlingen som er dokumentert.

Kontaktperson hos NSD: Øyvind Straume

Lykke til med prosjektet!

Appendix III - Informed Consent Form

Vil du delta i forskningsprosjektet

«Utvikling av fysisk form, treningsbelastning, skader/sykdom og psykososiale elementer i ungdomsidrett?»

Dette er et spørsmål til deg som foresatt om ditt barn kan delta i et forskningsprosjekt hvor formålet er å undersøke hvordan fysiske egenskaper, treningsbelastning, skader/sykdom og psykososiale forholder utvikler seg i løpet ungdomsårene, og om det er ett forhold mellom dem. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for barnet ditt.

Formål

Gjennom ungdomsårene så er det mye som skjer med kroppen, blant annet så blir man i bedre fysisk form. Hvor fort og hvor mye man forbedrer sin fysiske form er forskjellig fra person til person, og vi vet i dag lite om hvor mye trening kan påvirke denne utviklingen for ungdommer i vekst. I dette prosjektet vil vi undersøke hvordan unge ballspillutøvere utvikler seg gjennom tre år, og om vi kan se en sammenheng mellom utvikling i fysiske egenskaper, treningsbelastning, skader/sykdom og psykososiale elementer. Både fysiske egenskaper og psykososiale elementer vil bli målt årlig, mens treningsbelastning og skader/sykdom vil bli målt igjennom sesongen. Informasjon om dette temaet kan være med å forbedre vår forståelse for hvordan man utvikler seg i ungdomsidretten, som videre kan være med å forbedre måten vi trener på i ungdomsårene.

Dette forskningsprosjektet er et samarbeid mellom Norges idrettshøgskole og Universitet i Agder testingen skal gjennomføres på Norges idrettshøgskole eller Universitet i Agder i 2021-2023.

Hvem er ansvarlig for forskningsprosjektet?

Institutt for fysisk prestasjonsevne ved Norges idrettshøgskole og Institutt for idrettsvitenskap og kroppsøving ved Universitetet i Agder er ansvarlig for prosjektet. Prosjektansvarlig er Live S. Luteberget, Bård Erlend Solstad og Truls Raastad. I tillegg vil to PhD-studenter være ansvarlige for den daglige driften av prosjektet.

Hvorfor får du spørsmål om å delta?

Ditt barn blir kontaktet om deltagelse i prosjektet fordi han/hun er en aktiv fotball- eller håndballspiller i alderen 13-17 år.

Hva innebærer det for deg å delta?

Prosjektet innebærer det at deltagerne må møte opp til fysiske tester 2 dager per år i tre år. Testene som vil gjennomført er utholdenhet (YoYo-test), hurtighet, styrke, spenst, høyde, sittehøyde, vekt og spørreskjema om psykososiale elementer. Spørreskjemaet inneholder spørsmål som spør hvordan deltagerne har det i hverdagslivet sitt og i treningskonteksten, hvordan de opplever atferden til treneren og lagfellesskapet, hvordan de vurderer sin egen fysiske helse, samt om de har det gøy på trening. Alle foresatte kan også gis mulighet til å se spørsmålene før deltagerne samtykker til å delta i undersøkelsen. Deltagerne bli bedt om å svare på spørreskjema om skader/sykdom hver 14.dag gjennom en app på mobiltelefon. I tillegg vil deltagerne bli bedt om å vurdere treningsbelastningen sin (på en skala fra 1-10) i tre perioder på 2 uker i løpet av sesongen.

I tillegg vil noen av deltagerne i prosjektet vil bli trukket ut til å være på følgende målinger:

Vi vil i løpet av sesongene 2021-23 i tillegg måle treningsbelastning. Dette skjer ved at deltagerne må ha på seg en GPS-enhet på trening i tre perioder i løpet av sesongen, der hver periode varer to uker. Dette innebærer at de har på seg en vest på trening (se bilde), hvor enheten er plassert. Deltagerne vil i forbindelse med øktene også bli bedt om å svare på noen spørsmål, inkludert en vurdering på hvor tung de syns treningen var (skala 1-10) og spørsmål om følelser og oppfatninger om treningen. I tillegg vil deltagerne i en av ukene bli bedt å gå med ett akselerometer for å måle sin daglige fysisk aktivitet. Dette akselerometeret skal de ha på seg (på hoften) i 7 dager.

Mulige ulemper med deltakelsen i denne studien er at deltagere må sette av tid til testing og trening. Gjennomføring av fysiske tester og trening innebærer alltid en viss risiko for skader, men det er ingen grunn til å anta at skaderisikoen er høyere ved deltakelsen i denne studien enn i sin vanlige trening.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du ønsker at barnet ditt skal delta, kan du når som helst trekke samtykke tilbake uten å oppgi noen grunn. Alle opplysninger om barnet ditt vil da bli anonymisert. Det vil ikke ha noen negative konsekvenser for barnet ditt hvis dere ikke vil delta eller senere velger å trekke samtykket. Det vil for eksempel ikke påvirke spilletid eller forhold til treneren om dere velger å ikke være med i studien, eller om dere velger å trekke deg fra studien underveis.

Personvern – hvordan vi oppbevarer og bruker dine opplysninger
Informasjonen som registreres om barnet ditt skal kun brukes slik som beskrevet i hensikten med studien. Dere har rett til innsyn i hvilke opplysninger som er registrert om barnet ditt og rett til å få korrigert eventuelle feil i de opplysningene som er registrert.

Navnet på deltagere i prosjektet er det eneste direkte personidentifiserende opplysning som vil registreres. Navnet vil lagres separat fra dataene, og dermed er det kun en kode som knytter deltagerne til opplysninger gjennom en navneliste. Dette betyr at informasjonen er avidentifisert. Det er kun autorisert personell knyttet til prosjektet som har adgang til navnelisten og som kan finne tilbake til deg. Det vil ikke være mulig å identifisere enkelte deltagere i resultatene av studien når disse publiseres

Hva skjer med opplysningene når vi avslutter forskningsprosjektet?
Prosjektet skal etter planen avsluttes 01.08.26. Vi er pliktet til å oppbevare data og separat navneliste i 5 år etter sluttdato for etterprøvbarhet og kontroll av resultatene. Etter dette, altså 01.08.31, slettes navneliste og dataene er deretter anonyme.

Dine rettigheter
Så lenge deltagere kan identifiseres i datamaterialet, har dere rett til:
- innsyn i hvilke personopplysninger som er registrert,
- å få rettet personopplysninger,
- få slettet personopplysninger,
- få utlevert en kopi av dine personopplysninger (dataportabilitet), og
- å sende klage til personvernombudet eller Datatilsynet om behandlingen av personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deltagere basert på deres samtykke.

På oppdrag fra Norges idrettshøgskole har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- Norges idrettshøgskole ved prosjektansvarlig Live S. Luteberget, på e-post: livesl@nih.no, eller telefon: 40043516, eller PhD-student Lars Martin Tingelstad på epost larsmt@nih.no, eller telefon: 909 27 805
- Universitet i Agder ved prosjektansvarlig Bård Erlend Solstad, på e-post: bard.e.solstad@uia.no eller telefon: 90114208.
- Vårt personvernombud: Rolf Haavik (epost: personvernombud@nih.no)
- NSD – Norsk senter for forskningsdata AS, på epost (personverntjenester@nsd.no) eller telefon: 55 58 21 17.

Med vennlig hilsen

Live S. Luteberget Truls Raastad Bård Erlend Solstad

Samtykkeerklæring

Foresattes samtykke

Jeg har mottatt og forstått informasjon om prosjektet *«Utvikling av fysisk form og treningsbelastning i ungdomsfotball»*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ☐ at mitt barn kan delta i prosjektet (den årlige målingen) som er beskrevet ovenfor
- ☐ at mitt barn kan delta i prosjektet (målt gjennom sesongen) som er beskrevet ovenfor
- ☐ at mitt barns opplysninger behandles frem til prosjektet er avsluttet 01.08.26, og at dataene kan lagres frem til 01.08.2031 for etterprøvbarhet og kontroll av resultatene
- ☐ at mitt barns resultater fra fysiske tester og treningsbelastningsdata kan deles med hovedtrener for sitt lag

----
(Signert av foresatte, dato)

(Fullt navn på barnet)