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The effect of wearable resistance training on different physical abilities in soccer players.

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Abstract

Introduction

Team sports are characterised as frequently episodes of short high-intensity running and longer periods of low-intensity activity, and these transitions are quite unpredictable and intermittent during a match. Performance is depended on a myriad of factors, and one of them are physical abilities, which can be required from strength, power and endurance training. Due to a desire of a more efficient and effective training method for improving sport performance, the focus on maximizing the transfer of the training to performance becomes more important. Wearable resistance training gives the possibilities to attach additional load on the body, which can be used to cause a greater stimulus on the working muscle in a specific team sport environment. Therefore, the purpose of this study was to examine the effect of wearable resistance attached on the lower limbs upon different physical abilities relevant for soccer performance.

Methods

Acute study: Twelve male soccer players (age: 23.3 ± 2.5 years; height: 179.2 ± 7.4 cm; body mass: 78.3 ± 7.1 kg) performed a change of direction test with different additional loads fixed on either the shank or thigh. Measurement consisted of total time, 90° and 45° split times. Longitudinal study: Twenty-three male junior soccer players (age = 17.3 ± 0.8 years; height =177.3 ± 6.3 cm; body mass = 70.6 ± 10.0 kg) were divided into a wearable resistance group (n = 11) and a unresisted group (n = 12) during a seven week training intervention. The wearable resistance group used additional load of 0.3-1.5% of body mass (BM) fixed on the individual' shanks and this was performed two times a week for 30 minutes each session during unpredictable movement patterns in their regular soccer training.

Results

Acute study: Significant effects of the different wearable resistance placement ($p<0.05$) and load ($p<0.001$) were found for total and split change of direction time performance. Change of direction times were higher with shank loading compared with thigh loading.

Longitudinal study: A significant effect of wearable resistance training was found on perceived exertion between the different groups ($F \geq 7.77$; $P = 0.011$).

Conclusion

Acute study: It was concluded that lower limb wearable resistance loading with different loads had an acute effect upon change of direction performance in male soccer players. Furthermore, that distal placement (shank vs thigh) with similar body mass load had a larger effect upon COD performance.

Longitudinal study: Perceived exertion responses indicated that wearable resistance training with regards of shank loading during regular soccer practice is causing an overall greater overload, which may lead to improvements in physical abilities relevant for soccer performance.

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- *Johannes Istvan Rydså*

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1. Introduction

Team sports have a high level of participation all over the world (O'Brien & Finch, 2014). The complexity of team sports causes that players performances are being influenced by a numerous of factors, categorized as: tactic, technique, physiques, physiology and mental abilities (Reilly, Williams, Nevill & Franks, 2000; Stølen, Chamari, Castagna & Wisløff, 2005). However, this article will only focus on the physical aspect in field team sports.

Team sports are characterised as frequently episodes of short high-intensity running and longer periods of low-intensity activity, and these transitions are quite unpredictable and intermittent during a match (Varley, Gabbett & Aughey, 2014). Additionally, team sports are characterised by movements like sprints, rapid acceleration, deceleration, jumping, blocking, tackling, throwing, kicking and directional changes (Stølen et al., 2005; Taskin, 2008; Paul, Gabbett & Nassis, 2016). Consequently, the level of physical abilities can distinguish characteristics between different level of the athletes (Driss, Driss, Vandewalle, Quièvre, Miller & Monod, 2001; Buchheit, Samozino, Glynn, Michael, Al Haddad, Mendez-Villanueva & Morin, 2014). However, the influence of the different abilities is specific for each sport concerning the level, rules, positions game conditions and duration of the game (Mohr, Krustrup & Bangsbo, 2003; Varley et al., 2014; Toda & Murakami, 2015).

1.1 Physical demands in team sport

Physical abilities such as endurance, sprint speed, acceleration, deceleration, strength, power, and change of direction are important key factors to achieve a successful performance in various team sports like rugby union, soccer and Australian football, including other types of team field-sports (Lockie, Murphy & Spinks, 2003; Stølen et al., 2005; Spinks, Murphy, Spinks & Lockie, 2007). In rugby, soccer and Australian football players run approximately a total of 5-15 km in a match, (Stølen et al., 2005; Coutts, Quinn, Hocking, Castagna & Rampinini, 2010; Vigne, Gaudino, Rogowski, Alloatti & Hautier, 2010; Varley et al., 2014; Toda & Murakami, 2015) and this distance consists of an average sprint distance of 10-20 m, which lasts 2-3 seconds, and a player performs approximately 20-60 sprints with a total distance of about 700-1000 m (Spencer, Bishop, Dawson & Goodman, 2005). Even though the total distance in a soccer game only consist of 1-11% sprinting, these high-intensity moments may have crucial impact on the result (Reilly et al., 2000).

Many of the high-intensity actions consist of an average of 50 turns during a soccer game, turning in soccer is mainly about comprising active forceful contractions, because the player wishes to keep the balance and control of the ball from pressuring opponents (Withers, 1982). Additionally, Póvoas, Seabra, Ascensão, Magalhães, Soares & Rebelo, (2012) reported that in a total of 103 registered playing actions in a handball game 60% consisted of stops and directional changes which makes it the most frequent applied high-intensity action in the game. With regards of soccer, a top-class player performs 726 ± 203 turns during a single match and the equivalent of 609 ± 193 of these turns are conducted in 0º to 90º in direction to the right or left (Bloomfield, Polman & O'Donoghue, 2007). Furthermore, team sport athletes are depended of low-intensity periods for removing lactate from the active muscles so that the athlete may performed better during periods/situations which requires high-intensity actions (Stølen et al., 2005). Therefore, abilities like strength and power are just as important as endurance in team sport (Wisløff, Castagna, Helgerud, Jones & Hoff, 2004). The physical demands lead researchers continually working to find more effective methods to improve physical abilities on team sport athletes.

1.2 Improving physical abilities

There are different ways to enhance the physical abilities, whereas the goal is to improve a greater force output in the athlete's lower limbs (Cronin & Hansen, 2006; Young, 2006; Hrysomallis, 2012). The most used training forms are resistance training, ballistic training, plyometric training, assisted training, and traditional sprint training (Newton, Kraemer & Haekkinen, 1999; Cronin & Hansen, 2006; Young, 2006; Hrysomallis, 2012; Hicks, 2018). All of these methods shows more or less to have a positive effect on relevant team sports measurements such as linear sprint, COD, jump performance and aerobic fitness (Newton et al., 1999; Østerås, Helgerud & Hoff, 2002; Wisløff et al., 2004; Spinks et al., 2007; Sheppard, Dingley, Janssen, Spratford, Chapman & Newton, 2011; Upton, 2011; Lockie, Murphy, Schultz, Knight & Janse de Jonge, 2012; Hermassi, Gabbett, Ingebrigtsen, Van Den Tillaar, Chelly & Chamari, 2014; van den Tillaar, Waade & Roaas, 2015). Also, a combination of some the methods provide beneficial effects on various physical abilities (Faigenbaum, McFarland, Keiper, Tevlin, Ratamess, Kang & Hoffman, 2007; Hammami, Negra, Shephard & Chelly, 2017). Nevertheless, the methods often showed no superior difference when comparing them to each other (Upton, 2011; Lockie et al., 2012; van den Tillaar et al., 2015; Falch, 2019). There is no doubt that these methods are beneficial for enhancement of physical abilities, but more experienced athletes will require a greater quantity of specificity, individualization and variations inducted in their strength and conditioning training regime (McGuigan, Wright & Fleck, 2012). An optimal transfer is depended of the specific adaptations to the nature of the training stress, which only may appear with training mimicking the sport competition (Young, 2006).

1.3 Specific strength training

Due to the desire of a more efficient and effective training method for improving sport performance, the focus on maximizing the transfer of the training to performance became more paramount (Young, 2006). The principle of specificity is more conducted in strength training context for team sport athletes (Myer, Ford, Brent, Divine & Hewett, 2007; Clark, Stearne, Walts & Miller, 2010). Moreover, specificity training is referring to that movement velocity performed in a specific training regime should be very similar to the movement performed in a sport competition (Van den Tillaar, 2004). In practice, this means that some training is more specific than others in the given sport. Therefore, training exercises such as traditional weight training with heavy resistance might not be the most efficient method for the athlete. Slow training with heavy loads is quite beneficial for enhancing strength, but perhaps isn't the best way for power development with higher velocity because of the considerable parts of deceleration through the movement, whereas resisted movement training allows the acceleration phase throughout the range of motion (Newton et al., 1999). The purpose of resisted movement training is to optimize the training effect by causing a greater stimulus to the working muscles than normal training with help of external load in the relevant sport context (Hrysomallis, 2012). Such specific training is expected to provide a good transfer to sport performance in a short term and for well-trained athletes, however, there is also a probability for negative occurrences such as increased risk of injuries, overtraining, muscle imbalances, and boredom regarding a long term perspective (Young, 2006).

1.4 Resisted movement training

Training with resistance is conducted in many different settings, resisted movement training is performed during walking, running, sprinting, jumping and throwing (Van den Tillaar, 2004;

Macadam, Cronin & Simperingham, 2017a). A popular form of resistance training is resisted sprint training. This type of training is widely used with the goal of improving acceleration for athletes who participate in competition, which demands speed and power for a successful performance (Spinks et al., 2007; Rey, Padrón-Cabo & Fernández-Penedo, 2017). The primary focus is to involve the strength levels in the lower limbs (hip extensors), simultaneously enhancing the kinematics of acceleration (Hicks, 2018). Resisted sprint training can be conducted with several different methods such as weighted sled, parachute, pulley system, uphill/incline sprinting, elastic band resistance and wearable resistance (Kristensen, Van den Tillaar & Ettema, 2006; Myer et al., 2007; Spinks et al., 2007; Martinopoulou, Argeitaki, Paradisis, Katsikas & Smirniotou, 2011; Rey et al., 2017). Furthermore, most of these methods can only be performed in a linear movement context as a supplement to the sport, which has often shown not to be any superior training method compared to traditional sprint training (Spinks et al., 2007; Luteberget, Raastad, Seynnes & Spencer, 2015; Rey et al., 2017; Gil, Barroso, Crivoi do Carmo, Loturco, Kobal, Tricoli, Ugrinowitsch & Roschel, 2018), and it even might be detrimental for enhancement of sprint performance in some occasions (Kristensen et al., 2006). Irrespective, wearable resistance training gives the athlete possibilities to train endurance, COD, jumping and sprinting with a resistance in more complex movement pattern (Macadam et al., 2017a; Dolcetti, Cronin, Macadam & Feser, 2019). Perhaps, wearable resistance can take resisted movement training to a higher-level of specific training for team sports athletes.

1.5 Wearable resistance training

There are many different training options which focus on specific adaptions regarding the requirements of the sport and the athlete (Hrysomallis, 2012). Wearable resistance training (WRT) is all about using external load on different segments of the body while performing the movements in the various sports, and this leads to a concept of training specificity (Macadam et al., 2017a). The purpose of WRT is to improve strength and neural activation by achieving stimulus from additional load while simultaneously not detriment the technical embodiment of the specific movement (Hrysomallis, 2012). As such purpose is particularly essential when the goal is to enhance speed and agility abilities (Cissik, 2004). Moreover, applying light weights with WRT allows the athlete to achieve high velocity and acceleration from performing a full range motion in the specific movement environment (Newton et al., 1999). On the other hand, the use of WRT as a tool for improving team sports athletes is in an initial phase, meaning the knowledge regarding optimal load, placement, exercise may yet be expanded.

External loads have been positioned on various places on the body to examine different effects, places such as the head, feet, trunk and arms has been applied in previous studies (Soule & Goldman, 1969; Ropret, Kukolj, Ugarkovic, Matavulj & Jaric, 1998; Simperingham & Cronin, 2014). However, the most common placement area with wearable resistance training is on the trunk followed by the lower limbs (Macadam et al., 2017a). Training with a trunk loading has shown to have great effects on running, sprinting and jumping by an increase in vertical force utilization during foot strike, enhancing braking forces, which may lead to improvement of the short-stretching cycle (Cronin & Hansen, 2006). Results showed that trunk loading has an acute effect on running, jumping and sprint performance (Konstantinos, Athanasia, Polyxeni, Georgios, Elias & Charilaos, 2014; Silder, Besier & Delp, 2015). Nevertheless, longitudinal studies using trunk load during a 6-7-week sprint training regime showed no superior difference compared to traditional sprint training (Clark et al., 2010; Rey et al., 2017), while significant improvements have been reported on running and jumping performance with additional load attached to the trunk during 3-8 weeks of training (Bosco, Rusko & Hirvonen, 1986; Rusko & Bosco, 1987; Khlifa, Aouadi, Hermassi, Chelly, Jlid, Hbacha & Castagna, 2010; Markovic, Mirkov, Knezevic & Jaric, 2013). Trunk loading requires a higher amount of load (5-30% BM) to achieve a training stimulus compared with the other types of placements (Macadam et al., 2017a), and too much load can result in technique adjustments which may cause a negative alteration in the athlete's movement techniques (Cronin & Hansen, 2006). Moreover, the specific overload and effect by using lower limb loading compared with trunk loading during sport movements, has caused an increased interest among researches to focus on training with lower limb resistance (Simperingham & Cronin, 2014; Macadam et al., 2017a; Couture, Simperingham, Cronin, Lorimer, Kilding & Macadam, 2018).

Lower limb loading has shown to have significantly acute effects on walking, running, sprinting and jumping with loads between 0.3-8.5% BM (Macadam et al., 2017a; Macadam, Simperingham, Cronin, Couture & Evison, 2017c). With regards of running, lower limb loading placement of $\leq$1.4 % BM appears not to detriment the natural running movements (Martin, 1985; Claremont & Hall, 1988). Furthermore, Simperingham & Cronin, (2014) reported that trunk loading with 5% BM did not change the sprint performance on 25 m sprint, whereas attachment on the legs with an identical amount of load showed a significant reduction in sprint time on distance $\geq$10 m. With regards of vertical jumping, non-significant difference between upper and lower body conditions on both additional loads with 3% and 6% occurred on measuring jump performance (Macadam et al., 2017c). However, lower limb loading showed a greater metabolic response compared to trunk loading while walking at 5.6 km/h for 20 min (Soule & Goldman, 1969), which may occur from that it would require a greater amount of load when it is placed closed to the athlete's center of mass to attain similar stimulus (Cronin, Hansen, Kawamori & Mcnair, 2008).

Lower limb loading can be attached to the thigh, shank or ankle, and is reported that the metabolic response is greater with a more distal attachment than a proximal position (Macadam et al., 2017a). Notwithstanding, Claremont & Hall, (1988) noted that ankle load placement may not always be a suitable attachment, since the subjects experienced uncomfortable during running and their joint range of motion were diminished. Hence, wearable resistance training with shank and thigh placement has expanded, many studies are using both placements simultaneously (Bennett, Sayers & Burkett, 2009; Simperingham & Cronin, 2014; Simperingham, Cronin, Pearson & Ross, 2016; Macadam, Simperingham & Cronin, 2017b; Macadam et al., 2017c; Couture et al., 2018; Simperingham, 2019), while others focus on the different effects between them (Feser, Macadam, Cronin & Nagahara, 2018; Field, 2019). Field, (2019) compared proximal and distal lower limb loading on metabolic response with endurance runners during a submaximal run, results showed that distal loading had nearly double effect on oxygen consumption (2.56 ± 0.75%) compared to proximal loading (1.59 ± 0.62%) with every 1% BM of load added. Comparatively, Martin, (1985) reported also a greater increase in oxygen consumption when using loads fixed on the feet (3.3% and 7.2%) compared to thigh placement (1.7% and 3.5%) with loads of 0.69 and 1.39% BM, respectively. Moreover, Feser et al., (2018) also compared different placement (thigh vs. shank) during a 50 m sprint with 2% of BM loading, results showed a greater alter in step kinematics with using loads on the shank compared to thigh, whereas no significant changes appeared in sprint times between the conditions. Additionally, Macadam et al., (2017b) investigated different placements on lower limbs resistance in form anterior versus posterior positioning, and showed no significant difference between the conditions with loads of 3% BM during sprinting.

With regards to chronic effects, to date there are only conducted two longitudinal studies with lower limb wearable resistance training. Pajić, Kostovski, Ilić, Jakovljević & Preljević, (2011) with 6 individuals (gender not reported) used 2.5% BM placed on the ankles in a 6-week sprint training regime, results showed a significantly decrease in stride frequency (-5.6%), while an increase in stride length (5.3%) with no significant effects on the running speed. Secondly, Simperingham, (2019) investigated the effects of using lower limb loading during 6 weeks of speed training on male rugby athletes. The loads were placed on both shank (1/3) and thigh (2/3) with loads ranging from 3 to 5% BM. Small improvements in the acceleration phase and in hip strength especially during fast movement velocity were found. Changes at flight and contact time during the acceleration phase, but there was no evidence of enhanced maximal velocity in the WRT group. Longitudinal studies with wearable resistance training with lower limbs loading regarding COD, jumping and running has not yet been explored.

1.6 Applying wearable resistance in a team sport context

The goal with wearable resistance training is to enhance the physical abilities without detrimental the specific movements and technique embodiments in the sport (Dolcetti et al., 2019). Previous longitudinal studies regarding team sport athletes have conducted wearable resistance training as supplement training, which doesn't include unpredictable movements in a sport context (Clark et al., 2010; Rey et al., 2017; Simperingham, 2019). Perhaps, using wearable resistance during regular team sport practice would enhance intermuscular coordination and make certain that muscles are prepared to any newly gain force-generating capacity (Young, 2006). Additionally, most studies used only a linear movement pattern or in vertical direction (Macadam et al., 2017a), meaning utilization of wearable resistance during directional changes is yet unexplored. Therefore, this study will firstly investigate the acute effects of different placements and number of loads attached on the lower limbs (shank and thigh) with team sports athletes upon change of direction (COD) ability. Secondly, the effects of a longitudinal use of lower limbs resistance with team sports athletes during their regular team sport practice upon different physical abilities will be investigated.

It was hypothesized that wearable resistance of would have an acute effect on the COD performance, i.e. athletes run slower compared to unresisted CODs. According to literature the more distal placement, the greater effect on the athlete during linear movement pattern (Feser et al., 2018; Field, 2019). This was also hypothesized to occur upon COD times. Therefore, shank loads existed of 1, 2, 3% of BM, while thigh loads were 1, 3, 5% BM in the study. A such distribution was hypothesized to make the difference between the conditions less.

With regards of the training intervention, it was hypothesized that applying wearable resistance training with soccer players in their regular training regime will improve physical abilities relevant for performance more than the regular training group due to the increased stimulus on the working muscles, while sustaining the specific movement patterns.

2. Methods – Acute study

2.1 Experimental approach to the problem

In order to compare the effects of different loads and placement of wearable resistance on lower limbs resistance upon the COD performance, a repeated measurement design was applied in which the subjects performed a COD test with three different loads and two different load placements (shank and thigh). The independent variables were six different conditions used when performing the COD test, and the dependent were total time and split time of the COD test. To avoid any form of learning effects a familiarization day was applied, and the testing was conducted with a randomised cross-over design with enough time to clear out any chronic effects.

2.2 Subjects

Twelve healthy and injury-free males (age: 23.3 ± 2.5 years; height: 179.2 ± 7.4 cm; body mass: 78.3 ± 7.1 kg) participated in the study. The subjects were active soccer players ranging from the second to fifth National Division. All the subjects had experience with some sort of COD tests, but not with wearable resistance training. The study was approved by the Norwegian Centre for Research Data and performed according to the Declaration of Helsinki. All the participants were fully informed of the nature of the study before providing their written consent to participate. The experiment was conducted in November−December when the season's competition had just ended. Additionally, subjects were informed to avoid strenuous training for 24 hours, consumption of alcohol for at least 12 hours, and consumption of a heavy meal less than 2 hours before each session.

2.3 Procedures

The testing was conducted on two different occasions, consisting of one familiarization day and one testing day, which were conducted with 2−7 days between each other. All the sessions started with a standardized warm-up protocol as specified by Van den Tillaar & von Heimburg, (2016), which consisted of a total 10 min with 1 of 7 different dynamic stretch exercises that were performed in the recovery period of 60 s between the 8 x 40 m runs, and the runs were performed at self-estimated intensity, starting from 60% of maximal sprinting velocity and then increasing by 5% until reaching 95% (Van den Tillaar & von Heimburg, 2016). After two minutes rest, the subjects performed two submaximal runs in the COD test with 2 min recovery in between. This was followed by performing the test with maximal effort. Each subject had two attempts in each condition. The order of the loads and placements were randomised for each subject to avoid a fatigue or learning effect.

The familiarization session consisted of collecting basic anthropometric data such as height and weight and making subjects familiar with equipment and procedure. During this session subjects performed two trials in the COD test with each load and both placements. Hence, 2 x unresisted runs, 2 x 1, 2, and 3% BM with shank placement and 2 x 1, 3, and 5% BM with thigh placement. After each run, a rest period of 2-3 min was conducted to avoid fatigue (Meylan & Malatesta, 2009; Condello, Minganti, Lupo, Benvenuti, Pacini & Tessitore, 2013).

The test day consisted of two runs on each of the seven different load conditions and used identical recovery time as in the familiarization session. On the familiarization day, all subjects started with unresisted runs, and then loads were fixed in a random order, while on the test day all runs were randomized. Every subject performed two sprints in each condition before changing to the next condition in which new loads were fixed/removed during the recovery periods. All the testing and warm-ups for all the sessions were conducted in an indoor hall and the subjects wore their own indoor soccer/jogging shoes.

The subjects started in a standing position 0.3 m behind a pair of photocells (Browser Timing Systems, Draper, UT, USA). The COD test contained a total distance of 25 m with 5 m between each turn with the first two turns of 90^0 (one right and one left turn) followed by two turns of 45^0. Each cone was placed 20 cm with an angle of 45^0 from every turning point (Figure 1). Total sprint times after four turns together with the split sprint times after the two 90^0 turns and the two 45^0 turns were measured with three pairs of photocells (Browser Timing Systems, Draper, UT, USA). The first pair had a height of 0.3 m while the last two pairs of photocells were placed at a height of 0.7 m (Figure 1).

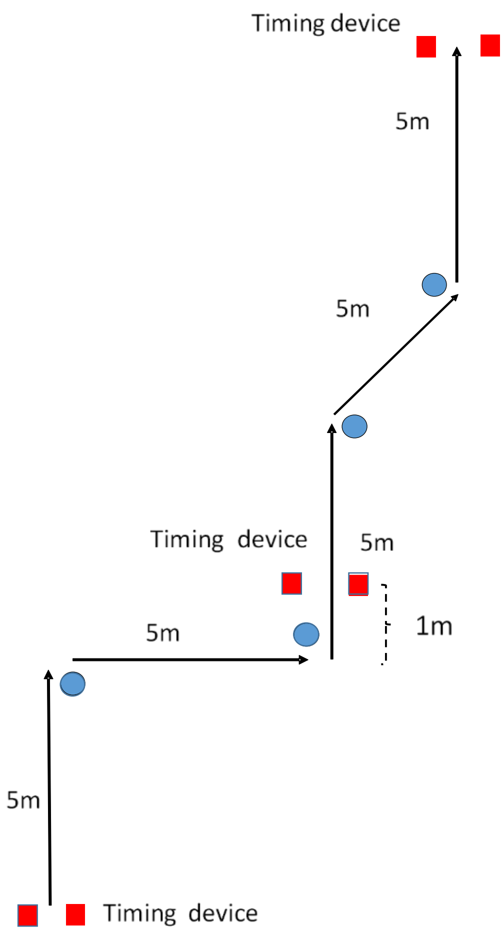

Figure 1. Change of direction (COD) test.

2.4 Wearable resistance

The subjects wore a pair of leg sleeves and compression shorts (Lila™, Sportboleh Sdh Bhd, Kuala Lumpur, Malaysia) with different loads attached to them. The load was regulated using fusiform shaped loads of 50, 100, 200, and 300 g, which could be attached to the garments by a Velcro backing. All the loads were estimated to the nearest 50 g on every run and 300 g were only used on the thigh condition. Placement of the loads was in accordance with the loading scheme protocol of (Field, 2019), but with some practical modifications. Loads were placed from most distal to proximal on the leg. The first load was attached horizontally, laterally and at the most distal point with the heaviest part placed anteriorly on the leg, while the next load was placed the opposite way (medial) with the heaviest part posterior on the leg. Additionally, the thigh condition loads were placed more laterally to avoid affecting the natural running gait during the heaviest loading (Figures 4 and 5).

Figure 2. Illustration of 1% BM resistance with shank condition for a 70 kg soccer player.

Figure 3. Illustration of 3% BM resistance with shank condition for a 70 kg soccer player.

Figure 4. Illustration of 1% BM resistance with thigh condition for a 70 kg soccer player.

Figure 5. Illustration of 5% BM resistance with thigh condition for a 70 kg soccer player.

2.5 Statistical analysis

Descriptive statistics were presented as means and standard deviations. Data was checked for normal distribution by using the Shapiro Wilk test. A two-way analysis of variance (ANOVA) with repeated measures was used to compare the effects of different wearable resistance conditions upon total and split times (90° and 45°). After significant differences were located on sprint times and split times, post hoc comparisons with Holm-Bonferroni corrections was applied to determine exactly where the differences occurred. If p-values for sphericity (Mauchly's test) assumptions were violated, corrections with Greenhouse-Geisser were reported. The level of significance was set at $p < 0.05$. Analysis was performed with SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA). Effect size was evaluated with partial eta squared (η^2) where $0.01 < \eta^2 < 0.06$ constituted a small effect, $0.06 < \eta^2 < 0.14$ a medium effect, and $\eta^2 > 0.14$ a large effect (Cohen, 1988).

3. Methods - Longitudinal study

3.1 Experimental approach to the problem

In order to examine the effects of wearable resistance training with lower limb placement upon different physical abilities relevant to soccer performance, a matched randomized two-group design was used to compare the training effects of resisted and unresisted in regular soccer exercise. The independent variables were wearable resistance group (WR) and unresisted group (UR), while depended variables were the physical abilities measured by five different tests. After finished pretesting, the participants were allocated the different groups based on their COD test performance. Additionally, the subject's preferred position was also considered during the match randomization process, because to eliminate inequalities regarding physical demands (Stølen et al., 2005). The wearable resistance training was added to the subjects regular training regime and the subjects were told to continue with their normal everyday habits to reduce the impact of uncontrolled variables. Also, subjects had to require a training attendance of ≥80% to be a part of the experiment's final data.

3.2 Subjects

Twenty-three male junior soccer players (age = 17.3 ± 0.8 years; height =177.3 ± 6.3 cm; body mass = 70.6 ± 10.0 kg) volunteered to participated in the longitudinal study. The participants were very active soccer players, which trained five times a week and all had experience with strength training, but not in form of wearable resistance training. The study was approved by the Norwegian Centre for Research Data and performed according to the Declaration of Helsinki. All the participants were informed about the study before the testing procedures begun. A consent scheme was given to all the participants, which required a consent of parents/guardian if participants were under 18 years old. The experiment was conducted in the soccer pre-season period (January-Mars).

3.3 Procedures

Before the training intervention, it was conducted two different days of pretesting followed by a 7-week training period, which ended by two days of post testing. The goal was to test the players physical abilities, and to avoid fatigue the tests were conducted on two different occasions. First test day consisted of an endurance test, while second day consisted of four different tests: COD, sprint, repeated sprint and jumping. On the second day of the testing, COD, sprint and jumping were conducted first, followed by the repeated sprint test conducted to avoid possible fatigue. The subjects were familiar with testing such as endurance, repeated sprint, sprint and jumping, but testing COD was quite unfamiliar for the majority. The test day started with collecting basic anthropometrics such as weight and height. Height was measured with a roller height measure tape (W7959 KaWe) and weight was measured with a stand scale (Soehnle Professional, 7730/7830). The subjects performed the identical warm-up protocol conducted in the acute study on each of the test days (Van den Tillaar & von Heimburg, 2016). The subjects were divided into different test groups to increase the efficiency and the same order of performance maintained in both pre- and post-tests. All the testing and warm-ups for all the tests were conducted in an indoor hall with rubber surfaces, and the subjects were wearing their own indoor soccer/jogging shoes. However, the training period was conducted outdoors on an artificial grass surface.

The training period consisted of the players performing their regular soccer training five times (one training at the gym) a week. Participants were divided into a WR group (n = 11), which used additional load attached to the individual' shanks, and an UR group (n = 12). The WR group used the wearable resistance two times a week (field training only) for 30 min each time, during activities which included an unpredictable movement pattern. The amount of load progressed from 0.3% to 1.5% BM and loads increased individually based on their completions of sessions (0.2% increment after every 2 completed sessions). Progression was also regulated by the subjects individual perceived exertion retrieved by a Borg RPE scheme (ranging 1-10). The scheme was given to all the players in both groups after each training session, and rating consisted of 10 being the highest and 1 being the lowest level of perceived exertion. In addition, if the subject missed the intended wearable resistance training, sessions was replaced on a later occasion to assure a higher completion rate. Mentionable, the Borg RPE scheme was not applied after the extra sessions with wearable resistance.

3.3.1 Description of tests

Endurance ability. Testing endurance was done by a Yo-Yo Intermittent Recovery 2 Test (yo-yo IR2), which is a common test for measuring the endurance ability regarding a soccer performance (Bangsbo, Iaia & Krustrup, 2007). The test consisted of 20 m sprinting with a 180° turn in the end followed by new 20 m sprint, and this was conducted with a progression in speed noticed by audio beeps. Between each run, the subjects were allowed to rest for 10 seconds in an area of 5 m before performing the next run. The area was marked with cones and each subject had a running zone of approximately 2 m width. All the subjects ran so many times they managed before they got too tired or did fail to reach the line twice before the beep (one warning and then out). The total amount of meters on each subject was recorded and presented in the test results as a collectively average value.

Sprinting ability. The sprint test was conducted on a linear distance of 30 m, but 20 m sprint time was also measured in each run. Subjects were instructed to give maximal effort on every sprint and all the subjects had 3 trials with 2 min rest between. Sprint time was measured by three pair of electronic photocells (Browser Timing Systems, Draper, UT, USA), two pairs at the start and finish line and the last pair was placed at 20 m. The photocell pair on the start line had a height of 0.3 m, while the remaining pairs had a height of 1 m to avoid participants just breaking the beam with arms or legs. All the subjects started in a standing position 0.3 m behind the first photocell pair.

Repeated sprint ability. The repeated sprint test was conducted on the same track as the 30 m sprint test. Each subject had to run 8 maximal effort sprints with 30 m, and after every completed run they had to jog to the same starting line to be ready for the next sprint. Interval time were 30 seconds on each sprint, so the active recovery was the remaining time after the sprint was completed (approximately 25 seconds). The interval times was measured with a stopwatch, and verbal feedback was given to enlighten the subjects how long time they had left before the next sprint. A laser (LaserSpeed, Musclelab) was used to measure speed, and step kinematics was measured by an infrared optical contact grid (Ergotest innovation, Porsgrunn, Norway, IR-contact mat ML6TJP02). Variables such as average time, fastest time, slowest time and percentage of decrement time were recorded during the test, based on former studies (Rey et al., 2017). The percentage of decrement consisted of this formula:

(Total time – (fastest time x number of sprints)) / (fastest time x number of sprints) x 100

Vertical jump ability. A countermovement jump (CMJ) test was conducted to examine the jumping ability. The test was performed with infrared optical contact grid (Ergotest innovation, Porsgrunn, Norway, IR-contact mat ML6TJP02) for measuring contact time and flight time which provides an CMJ index. The subjects were instructed to perform a fast-downward movement to a self-determined knee flexion angle followed by an instantly fast vertical counteract movement leading to a jump with outstretched legs and finishing in the same starting position (Gil et al., 2018). All this performed in one sequence as fast as possible with both feet leaving the ground and landing simultaneously. Additionally, the arms were placed on the hips to focus on the leg and hip power and reduce any technical inequalities (Pagaduan, Pojskić, Užičanin & Babajić, 2012). The subjects performed 3 trials each with about 1 min rest between and any trials considered as deviate from the given instructions was repeated.

Change of direction ability. The COD test procedure was completely identical to the COD test conducted in the acute study. Except, subjects performed 3 trials and each run was with unresisted condition.

3.4 Wearable resistance

The subjects wore a pair of leg sleeves (Lila™, Exogen™, Sportboleh Sdh Bhd, Kuala Lumpur, Malaysia) with different loads attached to them. Subjects used the sleeves during the whole training and were instructed to place the loads on during the unpredictable movement exercises. Different size of leg sleeves was chosen by measuring the subject's calf size and comparing it to the company's size chart. However, some individuals chose another size then recommend for increasing their comfort. The load was regulated with using fusiform shaped loads of 50, 100 and 200 g, which could be attached to the garments by a Velcro backing. Amount of load was determined by the subject's individual percent of body mass measurement. Placement of the loads was identical to the protocol applied in the acute study.

3.5 Statistical analysis

Descriptive statistics were presented as means and standard deviations. Data was checked for normal distribution by using the Shapiro Wilk test and then a one-way analysis of variance (ANOVA) was used to compare the different groups (WR and UR) level of perceived exertion. After significant differences were located between the groups, independent t-tests was used to determine difference on the similar session. The level of significance was set at $p < 0.05$. Analysis was performed with SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA).

4. Results – Acute study

A significant effect of wearable resistance placement was found for total and split COD time performances ($F \geq 5.4$; $P \leq 0.040$; $\eta^2 \geq 0.33$). In addition, a significant effect was found for load in total and split times ($F \geq 11.4$; $P< 0.001$; $\eta^2 \geq 0.51$) with no significant interaction effects ($F \leq 1.9$; $P \geq 0.155$; $\eta^2 \leq 0.14$). Post hoc comparison revealed that COD times were higher with shank loading compared with thigh loading. However, when compared pairwise only the 90° split times with 1% load were longer with placement on the shank compared with on the thigh (p=0.032, figure 6). Furthermore, comparing the same 3% load with different placement showed significantly higher COD times when placed on shank compared to thigh on both total time (p=0.004) and 90° split times (p=0.003), while 45° split times (p=0.09) showed no significant difference between the conditions.
Moreover, the unresisted COD times were significantly shorter in total time and in the 45° split times compared to the loading conditions, while with the 90° split times increase significantly with 2% shank and 3% thigh loading. Furthermore, did total COD time increase between 1% with 3% shank and 1 to 3% thigh loading. 90° split times also increase between 1 and 3% thigh loading and between 2 and 3% loading. 45° split times only increased significantly between 1 and 5% thigh loading (Figure 6).

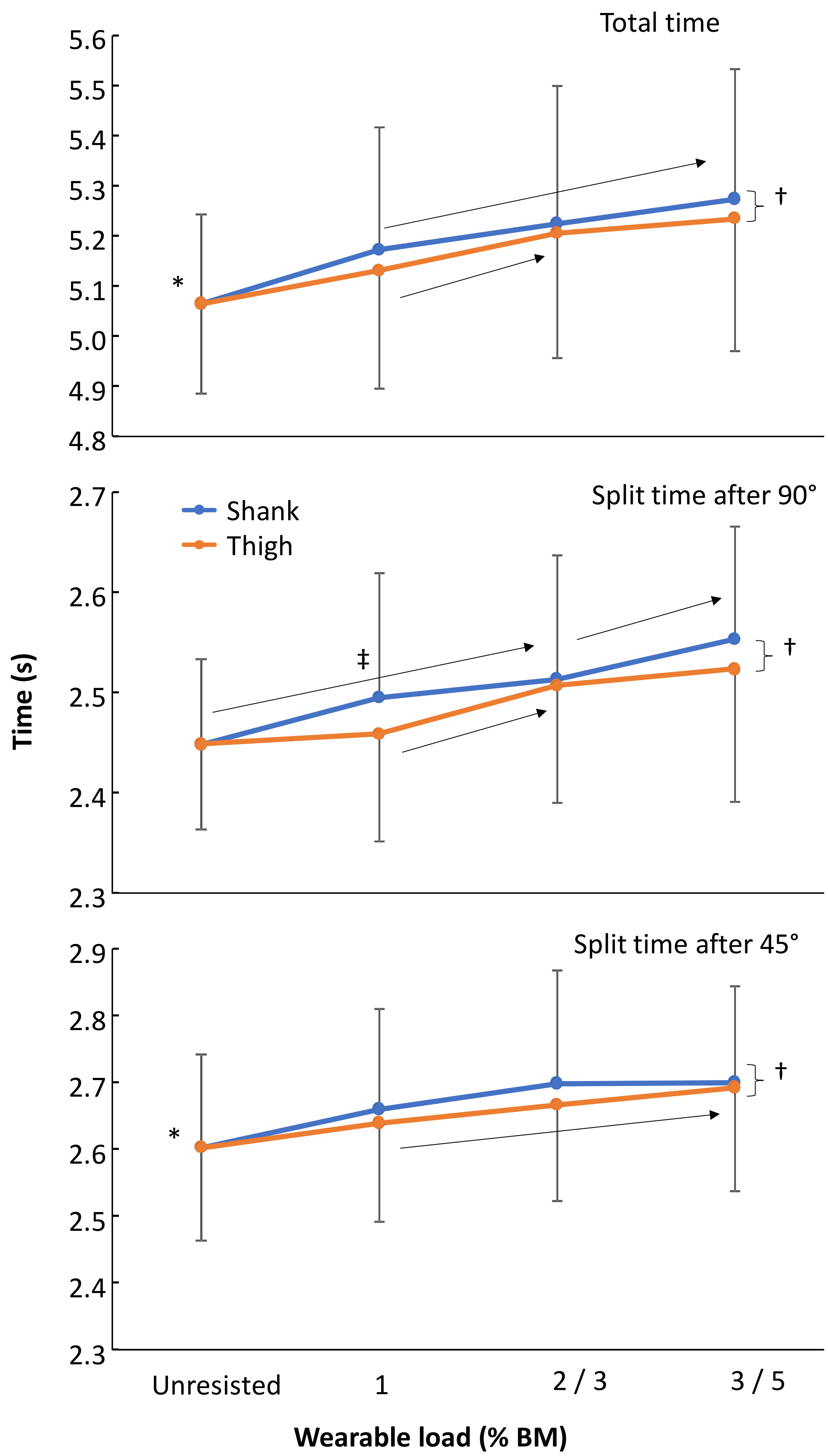

Figure 6. COD times (mean ± SD) for both conditions (shank vs. thigh) and different amount of resistance (0-5% BM). 2-3% BM = shank 2% and thigh 3% BM, 3-5% BM = shank 3% and thigh 5% BM.
† indicates significant difference ($p < 0.05$) between the two placements (shank vs. thigh).
* significant difference ($p < 0.05$) with all the other loads.
→ indicates a significant difference ($p < 0.05$) between the two conditions and all those to the right of it.
‡ indicates significant difference ($p < 0.05$) between placements with identical load.

5. Results – Longitudinal study

Unfortunately, the coronavirus pandemic occurred in Norway a week before the planned date of post testing procedures, which made it impossible to retrieve this data. Despite of this accident, the training regime was completed with collected data of perceived exertion after each session. A significant effect of wearable resistance training was found on perceived exertion between the different groups ($F \geq 7.77$; $P = 0.011$). However, independent t-tests revealed only significant difference between groups on session 4 ($p = 0.02$) and session 11 ($p = 0.05$), (figure 7).

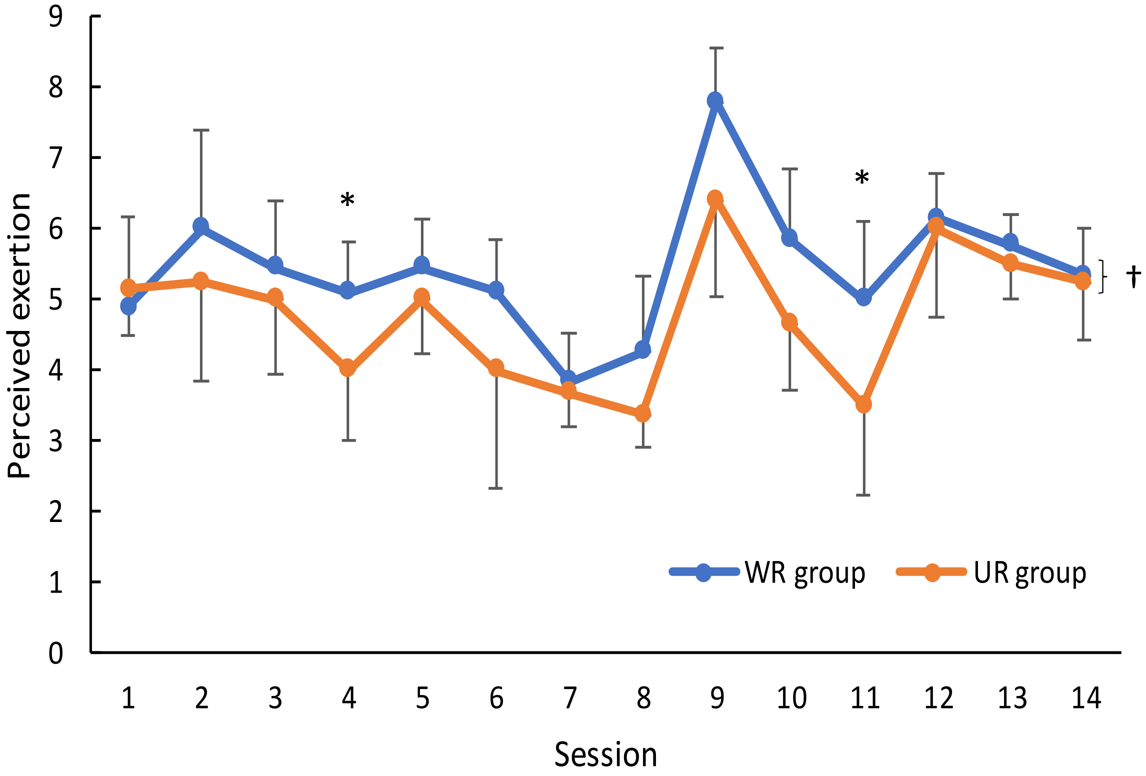

Figure 7. Borg RPE scale measurement of perceived exertion (mean ± SD) after each training session.

***** indicates significant difference ($p < 0.05$) between the groups on the exact session.

† indicates significant difference ($p < 0.05$) between the groups on all sessions.

6. Discussion – Acute study

The purpose of this study was to investigate the acute effect of different placement and loads of wearable resistance attached to the lower limbs on the change of direction ability in soccer players. The main findings were that wearable resistance placed on the lower limbs with loads of 1−5% of BM increased total and split times in a COD performance and that this effect was larger with shank loading compared with thigh loading.

The acute increase in time with lower limb loading on the COD test is comparable with the findings of Simperingham & Cronin, (2014) and Simperingham et al., (2016), who reported a significant increase in total sprint time (3.3 and 2.0%, respectively) during respectively 25 m non-motorized treadmill sprinting and 20 m over-ground sprinting with a loading placed of 5% BM on both shank and thigh (whole leg). This was similar to the total distance of the COD track. In contrast to the present study, the use of a lower loading of 3% of BM placed on the whole leg showed no differences in sprint time compared with unresisted conditions during a 20 m sprint (Simperingham et al., 2016; Macadam et al., 2017b). Furthermore, Feser et al., (2018) reported no significant differences between using shank or thigh placement of 2% of BM loading on 10 m sprint time compared to unresisted sprinting, indicating that wearable resistance seems to have a larger impact upon COD movements than on straight-line sprinting. This is also explainable by the fact that due to the change of direction the limbs must decelerate and re-accelerate more in several directions, which would cost more energy and coordination. Furthermore, the influence of small loads of wearable resistance (1%) seems to have more effect when the athlete is already at speed. In the present study, a noticeable effect with 1% loading was found in the second part of the COD track (45° split times), which was in accordance with 2.4−3% of BM loading on whole leg during the 10 m to 20 m in a sprint (Bennett et al., 2009; Macadam et al., 2017b).

The effect of lower wearable resistance was larger with shank loading compared to thigh loading, which was consistent with previous studies in terms of velocity, kinematics, and metabolic response measurements to distinguish between shank and thigh loading during running and sprinting (Feser et al., 2018; Field, 2019). Furthermore, shank placement provides a greater effect stimulus compared to thigh placement when using identical loads of 1 and 3% (Feser et al., 2018; Field, 2019), which is the result of greater inertia due to a more distal loading (Macadam et al., 2017a). At 1% loading only a significant difference in the 90° split times was found (+1.5%). This can be explained by the fact that it costs more time to initiate load and accelerate it when placed more distally on the limb due to moment of inertia, as Feser et al., (2018) reported by lower step frequency (-2.1%) with shank placement regarding the acceleration phase of the sprint. Furthermore, with 90° turns the participant has to decelerate more each time and re-accelerate again than with 45° turns (Nygaard Falch, Guldteig Rædergård & van den Tillaar, 2020), which is also influenced more by distal loading as shown by the increased times with the increased loads on the shank (2 to 3% load). When the participant is at full speed, the difference in load placement is much less and therefore no differences were found for the 45° split times. This was also visible with the 3% load in which the total time and 90° split times were higher with shank load placement vs thigh loading and no differences were found with the 45° split times (Figure 4).

In addition, the 45° split times only increased between 1 and 5% on thigh loading, which may be because shank loading of 1% BM was already causing a lot of overload to the athletes. In this case, the change from 1 to 3% shank loading is not as steep compared to the 1 to 5% thigh loading, but from unloaded to 1% BM the process is considerably greater. Similar findings were also reported in acute oxygen consumption during submaximal running between the two placements (Field, 2019).

Some limitations of the present study were that no joint and step kinematic or kinetic and muscle activity measurements were performed that could give more insights into what exactly changes – e.g. shorter steps, lower knee flexion or more proximal muscle use (Macadam et al., 2017a; Macadam et al., 2017b; Macadam et al., 2017c; Feser et al., 2018) − with wearable resistance during CODs. In addition, only CODs with 45° and 90° turns were performed, which are mainly used in soccer (Bloomfield et al., 2007), while it is not certain what the influence of wearable resistance on lower limbs is in turns of more than 90° change of direction. Another limitation was that the subjects were male soccer players, which leaves the knowledge of the effect of wearable resistance with similar lower limb loads in female athletes unknown. Furthermore, only acute effects of load and placement upon COD performance were examined and so this does not necessarily explain the longitudinal effects of wearable resistance upon COD performance. The lack of knowledge should be considered in terms of future studies, in which kinematic, kinetic and muscle activation measurement should be included and longitudinal effects of wearable resistance on the lower limbs on COD performance in team sport players should be conducted.

7. Discussion – Longitudinal study

The aim of this study was to examine the longitudinal effects of lower limb wearable resistance training with soccer players during their regular training upon physical abilities relevant for performance. Unfortunately, post testing was not conducted due to the coronavirus pandemic. In this case, it was impossible to investigate the effects of wearable resistance training on the different physical abilities relevant for soccer performance. However, the entire training period was completed and data of perceived exertion from all the players was collected after each session. The results showed an overall significant difference on perceived exertion between the different groups during the training period. Naturally, the wearable resistance group reported higher perceived exertion values due to additional weight placed on the body, in which causing a greater metabolic cost during running (Ackerman & Seipel, 2016). Correspondingly, Field, (2019) reported higher perceived exertion correlated with an increase in loading when using shank placement during submaximal running.

Interestingly, in the present study difference between the groups seems to be less during the last three sessions when the player wore their heaviest loads. Perhaps, when the players had adapted > 1.1% loading, it did not feel so much different when the load increased compared with the change from < 1.1% loading. Comparable with findings in the acute study, which reported a greater change from unresisted to 1% loading than from 1 to 2% loading in COD total times. Furthermore, Field, (2019) showed similar change during submaximal running with shank placement regarding acute oxygen consumption. However, this was not the case regarding perceived responses in the same study, where the ratings seems to have a more linear curve from unresisted to 2% loading (Field, 2019).

In the present study, players wore the shank loading for only 30 minutes during unpredictable movements in the training sessions. Possibly, a such method and training progression resulted eventually in enhancement of the anaerobic energy system, which made the perceived exertion responses less different between the groups during the last 3 sessions. In accordance of Rusko & Bosco, (1987) who stated that recruitment and adaption of fast-twitch muscle fibres had occurred during 4 weeks of weighted vest training with 9-10% of BM. The athletes wore the vest all day from morning to evening, including either every or every other endurance training. Rusko & Bosco, (1987) argued that the enhancement of fast-twitch fibres was recruited during lower intensity exercise and sessions were some of the athletes trained unresisted.

The current study did not include measurement of metabolic responses such as oxygen consumption, heart rate or lactate accumulation. However, previous research suggests that perceived exertion is a more reliable measurement regarding exercise intensity during soccer, due to intermittent activation of both aerobic and anaerobic energy systems (Bangsbo, 1994), and it’s particular an easy and not expensive method to use for measurements of soccer training and match play intensity (Impellizzeri, Rampinini, Coutts, Sassi & Marcora, 2004). However, received exertion rating only indicates the individual responses to the applied training dose

(Borg, Ljunggren & Ceci, 1985). Therefore, it would be interesting to investigate the impact of wearable resistance training in soccer upon more external training loads such as distance, high-speed running, and different play involvement compared with unresisted condition.

Some limitations of the current study were due to the lack of post test data, meaning this study must be conducted again to examine the training effects upon different physical abilities. Notwithstanding, perceived exertion results shows that this study is feasible, and it will provide a significant greater training overload with shank placement during soccer sessions. However, this study would only provide information of junior male soccer players, which leaves knowledge of wearable resistance with females, seniors and other types team sports still unknown. Also, the current study used loads between 0.3 to 1.5% of BM and every session had a duration of 30 minutes, which both may be increased based on perceived exertion. Another limitation is that the current study only used physical tests to examine the effect of lower wearable resistance training during a soccer specific movement environment, which leaves the knowledge of technical and tactical performance unknown.

8. Conclusion

In summary, it was concluded that lower limb wearable resistance loading with different loads had an acute effect on change of direction performance in male soccer players. Furthermore, it was demonstrated that distal placement (shank vs thigh) with similar % BM load had a larger effect on COD performance, particularly in turns with 90° compared with 45°, which is probably due to the increased moment of inertia during accelerating and decelerating the limbs during the turns. Therefore, shank loading during training could have a larger effect on performance with even less loading to induce some adaptation. Longitudinal effects with lower wearable resistance upon COD performance are still unknown, due to the coronavirus pandemic post testing was impossible to conduct. However, perceived exertion responses indicated that wearable resistance training with regards of shank loading during regular soccer practice is causing an overall greater overload, which may lead to improvements in physical abilities relevant for soccer performance.

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