Håkon Laugsand

Phase specific CoD in elite level team sports

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ABSTRACT

Change of direction (CoD) is a fundamental skill in a variety of court- and field-based ball sports. Based on the force momentum relationship CoD performance is based on the ability to generate horizontal force. However, tests of physical performance tend to focus on the ability generate vertical force. Furthermore, CoD is made up of two phases (initial acceleration to deceleration and re-acceleration) that represents different qualities and not captured with the current outcome measurements of overall time. The aim of this study is to determine how different tests of physical performance (horizontal and vertical) relate to overall and phase specific change of direction outcome measurement. 15 male elite handball-players (age 21±1.6 years, height 192±6.5 cm, body weight 96 ± 10.8 kg) completed a battery of tests consisting of two linear unloaded sprints (20m) and the modified 505 test with two left and right foot turns from a two-point start prior to five left and right unilateral lateral jumps. Both CoD and lateral jumps were performed with a 3kg external load provided by a motorized resistance. Overall time was used as outcome measurement for both sprint and the m505 test with the additional phase specific times (phase 1a initial acceleration to deceleration and phase 1b re-acceleration) for the m505 test. Then, both leg press (LP) (pneumatic resistance) and 5 countermovement jump (CMJ) (force platform) was tested. From the leg press average concentric power (LP_{avg_power}) was calculated, while both concentric peak ($CMJ_{con\_peak\_power}$) and average power ($CMJ_{con\_avg\_power}$) as well as peak eccentric peak power (CMJecc_peak_power) was calculated from the CMJ data. Relationships between test outcome measurements were determined using correlational analysis (Pearson r) with a significance level of $p<0.05$. Overall sprint time (2.83±0.11 s) had significant strong correlation with phase 1b (r= .77) , but neither with phase 1a (r= .10) nor overall time 505 (r= .32). Furthermore, Phase 1a had stronger correlation with overall time on the m505 test (r=.96) compared to phase 1b (r= .56, $p<0.05$), but the different phases did not correlate with each other (r=0.33, $p>0.05$). Neither leg press nor CMJ outcome variables were significantly correlated with neither sprint nor phase 1b time. However, LP_{avg_power} (r=0.73), $CMJ_{con\_avg\_power}$ (r=0.59) and $CMJ_{con\_peak\_power}$ (r=0.54) significantly correlated m505 overall time, and LP_{avg_power} (r=0.72), $CMJ_{con\_avg\_power}$ (r=0.61) and $CMJ_{con\_peak\_power}$ (r=0.58) significantly correlated phase 1a. Based on the lack of significant correlations between the different performance tests (sprint

and CoD), especially for phase 1a, and that there is no significant correlations between phase 1a and 1b, it appears that CoD tests with phase specific analysis provide unique information that might be of important for ball sport athletes. Both leg press and CMJ outcome measurements were correlated with phase 1a and overall m505 time but not with phase 1b and linear sprint performance. Based on current findings it appears that phase specific assessment of m505 tests provide unique information not quantified with CMJ, leg press, lateral jump or linear sprint tests which can be important to performance in ball sport athletes.

ACKNOWLEDGEMENT

Contents

CHAPTER ONE

INTRODUCTION

Background

Agility is a quality that is valued in a variety of sports. It is described as a quick whole-body movement with a change in direction or speed in reaction to a stimulus (Nimphius et al., 2018). However, there are conflicting meanings in sports science literature. Besides, it is commonly recognized that agility encompasses both reaction and movement. In contrast, CoD ability is defined as the ability to perform programmed change-of-direction (CoD) duties without being required to react to a stimulus. Agility is critical in invasion sports, like all football codes, for an attacker to elude defenders and preserve possession (Sawczuk et al., 2016). It entails the execution of various footwork patterns at multiple angles and speeds and may include deceptive motions. In theory, CoD is therefore a subcomponent of agility, that consists mostly of physical contributions, whilst agility in addition has mental attributions such as scanning, knowledge of play and anticipation (Kaur and Sinha 2020; Nimphius et al., 2018).)

Agility is therefore critical for defenders since it enables players to move fast and precisely to block attackers, mainly to regain control of the ball. As a result, agility is a complicated and diversified open skill in invasion sports. For instance, cricket batters may score many runs by executing a 180° turn around on either end of the field (Chaabene et al., 2018; Enright et al., 2018). The players visually target the crease as they alter their steps and decelerate before pausing and reaccelerating in the opposite direction. Thus, it is a movement where the method used and the place and time of the distance may be planned. Besides, the archetypal CoD 180 degree turn situation has been recreated and evaluated using tests like the "5-0-5" (Enright et al., 2018; Helme et al., 2019; Nimphius et al., 2018). As a result, more research has been completed on CoD, compared to agility, justified by the purely physical contribution and less uncertainty with results. (Gallo-Salazar et al., 2017; Sawczuk et al., 2018).

Usually, CoD tests are like the triangle test (TriT) and are often employed in evaluations in team sports (Worst et al., 2019). Often overlooking subcomponents of a CoD (deceleration, direction change, acceleration, eliminating decision-making processes), and investigating less holistic measurements such as overall time. Correlation tests reveal a broad range of explained variation (R^2=0.22 to 0.56) between linear speed (10m and 20m) and CoD performance in general (Worst et al., 2019). Another study indicates a variable relationship between jump performance and several CoD tests of R^2 = 0.06 to 0.83 (Nimphius et al., 2018). Additionally, studies demonstrate a variable association between maximal strength and CoD performance R^2 = 0.03 to 0.79 (Nimphius et al., 2018). Various correlations are thought to be the outcome of different test methodologies. However, various CoD tests have varying durations, lengths, and angular turns and are therefore impacted by multiple factors (Kadlubowski et al., 2019; Keiner et al., 2014). While a standardized examination of the tests seems impossible, their length and estimated total duration (TriT [10m, s>4] vs. IAT [65m, s<14]) indicate the tests' disparate needs (Kadlubowski et al., 2019). Furthermore, theoretically, athletes can have weaker performing phases during CoD test, but this could be overlooked as they compensate with stronger performing phases. Resulting in unique attributes going unnoticed. This can explain some of the contradicting research on the topic.

Pre-plannedCoD 5-0-5 situations do not arise in competition and may be exceedingly infrequent in invasion sports. While football codes may use set pieces and predetermined routes, they are more indicative of a tactical approach than an actual agility situation. Despite the attacking players preparing running path and angle of cut, the precise footwork and cut angle vary with the scenario of confronting defenders, ball position as well as teamates (Paterson et al., 2016; Tramel et al., 2019; Watts, 2015). The attacker may try to deceive a defense by performing an illusory action but may be forced to alter the movement plan if the deceptive act fails immediately. Similarly, a defender must continually study the attacker's movement to respond swiftly and adequately (Salmela, 2018). This demonstrates the agility's intricacy, flexibility, and unpredictability on the athletic field. Also, it explains the reason for a pre-planned CoD challenge is unlikely to replicate the agility requirements of invasion sports competition accurately.

Agility has been suggested in response to external stimuli as the capacity to quickly run and change direction (Sayers, 2015; Suarez-Arrones et al., 2020; Teo et al., 2016; Tramel et al., 2019; Zapartidis et al., 2018). The agility movement often involves acceleration (short distance <10 m), deceleration responding to the stimuli (balls, defense against opponents, exercise of tactical tactics), and then change to the new direction (Sayers, 2015; Suarez-Arrones et al., 2020; Teo et al., 2016; Tramel et al., 2019; Zapartidis et al., 2018). In addition, a significant determinant in agility performance, namely, change in direction speed (CoD). (Sayers, 2015; Suarez-Arrones et al., 2020; Teo et al., 2016; Tramel et al., 2019; Zapartidis et al., 2018) suggested an important limiting elements for the performance of athletes. The subject of agility research has been recently shifted to a topic called reactive agility. The research focus of sport-specific stimulation is based on sport-specific stimulation. The research has investigated the characteristics of speed and agility, particularly with the use of team sport players (Sayers, 2015; Suarez-Arrones et al., 2020; Teo et al., 2016; Tramel et al., 2019; Zapartidis et al., 2018). As sprint occurs every 70 seconds in a football match, with a duration of about 2 to 4 seconds per sprint (Suarez-Arrones et al., 2020; Teo et al., 2016; Tramel et al., 2019; Zapartidis et al., 2018).

Due to the complexity of agility, and the many subcomponents that can potially be explanatory for outcomes, CoD is often used in the scientific literature (Tramel et al., 2019; Zapartidis et al., 2018). Evaluating the links between CoD and sprint output in soccer is not uncommon. Reilly, Williams, Nevill, and Franks (2000) indicated that the best features for the fitness of young footballers (elite vs. sub-elite) are CoD or sprint time. Spencer, Pyne, Santisteban, and Mujika (2011) also performed cross-sectional research. These authors presented that interaction of repeated sprint and CoD across various ages was negligible to strongly favorable (ages 11 to 18). However, it should still be regarded as an independent fitness characteristic, although the connection between CoD and Sprint performance appears significant (Tramel et al., 2019; Zapartidis et al., 2018). 15 professional soccer players, including 10m of accelerated speed, flying 20m sprint, and CoD, were also screened by Tramel et al. (2019) to evaluate the performance contribution to soccer. The findings demonstrated the correspondence between 10m acceleration, 20m flying speed, and Zigzag's agility.

Numerous research investigations have indicated that applying force horizontally has a stronger effect on and correlation with sprint speed. For instance, wide leaps, hip thrusts, lateral jump training, and kettlebell swings stimulate the muscle required to extend the hip more than vertically loaded movements (Helme et al., 2019; Kaur & Sinha, 2020; McFarland et al., 2016; Neil, 2018; Raya-González et al., 2020; Sawczuk et L., 2016). This can potentially have similar requirements for attributes in CoD, and should therefore be incorporated to investigate relationship between the different skills.

Strength and power tests are used to explore what qualities and movements that determine performance such as CoD and sprint. By measuring lower body strength, force, acceleration, maximum speed, and agility as researchers assessed 40 rugby players at the national level, a more in-depth analysis, and showcasing critical components of physical performance is possible,(Hernández-Davó et al., 2021; Moya-Ramon et al., 2020; Paul & Nassis, 2015; Sawczuk et al., 2018; Sayers, 2015). Test of physical performance, such as the 1RM squat and squat jump show clear distinctions between players from the first and second divisions. Tous-Fajardo et al. (2016) have also highlighted the possibility of excellent predictors for the sprinting speed of professional rugby players for squat jump, countermotion leap, and relative power from SJ. Thomas et al. (2017) have also found similar results.

In NCAA Division I women's volleyball players, better vertical jumping hights were discovered compared to there counterparts of Division II and Division III. In addition to this, the vertical jumping height was projected to be a critical skill in basketball players for division I (Hernández-Davó et al., 2021; Moya-Ramon et al., 2020; Paul & Nassis, 2015; Sawczuk et al., 2018; Sayers, 2015). Vertical jumping height was similarly linked with the repeated sprinting capacity of players (RSA). The ability to exhibit optimal muscle strength and power is thus essential for the success of athletes. In brief, while a significant number of studies have conducted evaluations on the critical physical fitness elements that may influence the performance of team athletes, there is a critical shortage of knowledge about broader physical components such as lower body strength,phase specific CoD, horizontal and vertical jumps and sprinting in elite level team sports. Therefore, this research aimed to deal with these areas by clarifying the underlying processes.

Purpose Statement

Agility is one of the fundamental physical features of team sports . In this context, sport science and research linked to strength and conditioning tried to determine limiting variables for performance agility (Hernández-Davó et al., 2021; Moya-Ramon et al., 2020; Paul & Nassis, 2015; Sawczuk et al., 2018; Sayers, 2015). Conceptual and decisive elements and changes in CoD have been suggested as two key components under the concept of universal agility (Moya-Ramon et al., 2020; Paul & Nassis, 2015). But the agility test methods in the sports science field did not have a universal consensus (Sawczuk et al., 2018; Sayers, 2015). The present literature has a range of tests. Different energy systems were needed for these tests with a time range of 2 to 135 sec for CoD activities with primary vertical or horizontal forces generation (Hernández-Davó et al., 2021; Moya-Ramon et al., 2020; Paul & Nassis, 2015; Sawczuk et al., 2018; Sayers, 2015). Given team sports movement patterns, research into the agility tests, especially CoD, was minimal.

Recent researchers have proposed CoD testing similar to football CoD patterns, which are aimed at explaining how strength and derivatives are related, as well as how to achieve CoD performance (Hernández-Davó et al., 2021). Recent studies have been carried out in the CoD. These are the only studies we know that investigate the impact on CoD performance of the lower body maximum strength and strength. Hernández-Davó et al. (2021) separated the participants by assessing their single leg midnight pull strength into stronger and weaker groups (N kg-1). The findings showed that the upper group performed better in greater breakage power, propulsive force, braking impulse, and propulsive impulse. In comparison with the weaker group, the more substantial group exhibited a quicker post-CoD time. But the subjects were leisure athletes in both strong and weak categories. In addition, the sports they took part in were not the same (soccer, netball, and basketball) (Hernández-Davó et al., 2021). Whether the findings might apply to other populations is difficult to predict. Thus, this research will educate if similar results can be found in elite level handball players of the impacts of lower body and strength on straight sprinting, CoD performance as well as horizontal and vertical jumps.

The purpose was primarily to study CoD and its connection to horizontal and vertical jumps outcome variable on linear sprint as well as overall and phase specific CoD performane in elite handball players influenced by the lower strength attributes.

CHAPTER TWO

LITERATURE REVIEW

In this chapter, the contents are centered on a review of the existing research on the connections between athletes' lower body strength, power, and CoD performance. First, there are apparent differences from agility to CoD. A short description is given of two main components in agility performance, including perception and decisions and CoD speed. Second, in team sports, players' physical and biomechanical characteristics are presented with CoD. In particular, elements linked to muscle and CoD are addressed extensively, including lower body strength, skills, and acceleration. Following are the methods and training studies of CoD testing that concentrate on transferring impacts from strength and power training to CoD for athletes.

Defining Agility and the Change Direction Ability (CoD)

As previously mentioned, agility has been identified as a key motor skill for athletes participating in team sports (Serpiello et al., 2017; Venter et al., 2017; Worst et al., 2019). Agility has been proven to be the most important physical component for detecting talent in young soccer players by many scholars (Serpiello et al., 2017; Venter et al., 2017; Worst et al., 2019). Agility is described as "rapid whole-body movement with a change in velocity or direction in response to a stimulus" (Venter et al., 2017). According to their proposed theoretical model, two of the primary components that contribute to athletes' universal agility performance are perceptual factors and decision-making, which fall under the cognition category, and CoD, which falls under the category of physical capacity (Serpiello et al., 2017). Furthermore, agility is recently defined as the capacity to make reactive movements in either attacking or defensive situations (Suarez-Arrones et al., 2020). Agility is critical in many team sports, including basketball, soccer, rugby, and Australian Rules football (ARF) (Serpiello et al., 2017. These agility movements demand athletes to engage in intermittent high-intensity activities such as acceleration sprinting, deceleration halting and quickly changing directions (Chaabene et al., 2020). To gain a better understanding of the physiological and biomechanical characteristics of agility, various authors have examined the relationships between agility and athletes' physical capacities(Chaabene et al., 2020), which are discussed in detail in the following sections. The prevalent movement patterns in team sports often include a period of linear acceleration (5-30m), followed by a period of deceleration prior to a change in direction (Serpiello et al., 2017; Venter et al., 2017; Worst et al., 2019).

Additionally, athletes often change directions depending on their perception of their present position or their understanding of the game in an offensive or defensive scenario (Chaabene et al., 2018; Fiorilli et al., 2017; Maloney et al., 2017). Thus, the capacity to run with fast directional changes while responding to external cues has been defined as agility in recent research (Chaabene et al., 2018; Dugdale et al., 2020; Fiorilli et al., 2017; Maloney et al., 2017). Although the word "agility" has been extensively used in the existing literature, there is still no agreement on its precise meaning in sport science, sports medicine, and the strength and conditioning sector (Chaabene et al., 2018; Dugdale et al., 2020; Fiorilli et al., 2017; Maloney et al., 2017). For instance, twenty words such as preplanned movement, preset movement, rapidity, cutting maneuver, shuttle run, and reactive agility have been used in the literature. These terms have also been used to refer to athletes' agility performance in scientific publications.

Thus, those actions that enable athletes to accomplish a change of direction task without thinking have been characterized as CoD speed (CoDs) or CoD ability (CoD) (Oliver & Meyers, 2009). The bulk of CoDs and CoD tests are conducted in relatively confined settings, eliminating the requirement for participants to respond to external stimuli while doing their tasks (Dugdale et al., 2020). The "L" run, T-test, Pro-agility test, and Illinois agility run are the most often used tests for assessing CoD and CoD (Dugdale et al., 2020). In these tests, athletes begin in a stationary stance and accelerate before changing direction in the horizontal plane (Maloney et al., 2017). It has been claimed that the capacity to generate a rapid rate of force generation and high power outputs is associated with better athleticism in team sports athletes, including leaping, sprinting, and CoD performance (Maloney et al., 2017). Additionally, strength and conditioning coaches often aim to assist their players in achieving greater neuromuscular strength and power performance. As a result, this study's primary objective is to investigate the relationships between muscle characteristics, particularly lower body strength and power characteristics, and CoD performance.

To better understand agility, sports researchers divide several components into more controllable elements. This reductionist method is believed to abridge the evaluation and training for such attributes. One way to do this is to determine the several variables that contribute to agility performance. Researchers have used this approach to demonstrate CoD's ability to support agility performance (Dos' Santos et al., 2017; López-Samanes et al., 2020). As a result, researching CoD 5-0-5 in isolation may be beneficial for understanding agility performance in various invasion sports. Many studies on CoD 5-0-5 ability ensure comparative simplicity through assessment and quantification (López-Samanes et al., 2020). This testing originates from the low equipment requirements, the ease where many athletes may be estimated, the availability of normative data, and the high dependability associated with standardized test procedures.

Additionally, since biomechanical studies show that pre-planned side-stepping places less strain on the knee than side-stepping in response to a stimulus, another anticipated benefit of CoD 5-0-5 testing is a decreased chance of damage, including a anterior cruciate ligament injury.

In comparison, evaluating agility is more complex than responding to stimuli (Serpiello et al., 2017). Certain studies recognized the need to add a stimulus to assess agility and employed a flashing light gadget to drive the athlete to a new place (McFarland et al., 2016; Serpiello et al., 2017). While it seems to be a reasonably straightforward and readily controllable approach, this form of generic stimulus does not exist in the sports environment and lacks ecological validity (Freitas et al., 2016; Venter et al., 2017). Furthermore, comparing a generic stimulus to a more sport-specific stimulation elicited by an opponent's movement demonstrates that the former cannot discriminate between lower and better standard athlete groups (Hernández-Davó et al., 2021; McFarland et al., 2016).

Similarly, a general light-based stimulus elicits a different side-stepping strategy than a sport-specific stimulus possible. There is evidence that attacking and defensive agility are reasonably self-contained abilities (Suarez-Arrones et al., 2020). Thus, it demonstrates the agility's intricacy, flexibility, and unpredictability on the athletic field. This also explains why a pre-planned CoD 5-0-5 challenge is unlikely to replicate the agility requirements of invasion sports competition accurately. When more ecologically valid testing methodologies guide practice on agility performance, the research is guiding practice may be increased (Teo et al., 2016; Young & Rogers, 2014). In the recent sports research literature, evaluating agility in a one-versus-one case situation has been suggested (Maloney et al., 2017; McFarland et al., 2016). Such tests tried to recreate an agility situation like rugby or an Australian football match between an attacker and defense.

An example would be instructing the attacker to try to dodge a defender to cross the end-line without tagged while introducing the defender to try to label the attacker's body with two hands (Dos'Santos et al., 2017; Hernández-Davó et al., 2021). The scoring coordination is based on the nearness of one athlete to the other throughout the game and may be verified using video evidence. These tests have been reliable and have a high degree of face and ecological validity.

Several possible benefits of such tests include preserving perception-action links, the ability to measure both attacking (including deceptive actions) and defensive agility, and the ability to examine the CoD 5-0-5 method, movement speeds, and perceptual information. A disadvantage of this method is the limited perceptual information available while responding to a single adversary (Fox, 2018). While this situation is prevalent in various sports, there are several instances in which an attacker or defense must respond to several opponents or at the very least analyze the activities of a large number of players on the court or field (McFarland et al., 2016; Thomas et al., 2017; Tous-Fajardo et al., 2016). Further, the inherent variety of agility in sports complicates the construction of a credible test significantly (Suarez-Arrones et al., 2020). Another possibility is to qualitatively characterize agility performance using a checklist of technical factors and game-related contest results without acceptable quantitative result measurements.

Strength Training for Game Associated with CoD

Strength and conditioning practitioners must still discover programs in addition to conventional strength exercises that may aid increase CoD in real-world situations. Consider what makes game agility unique in comparison to straight sprints and CoD 5-0-5 testing. For instance, one critical distinction is deceleration (Salmela, 2018; Rouissi et al., 2016). There is also the beginning posture of the body. It optimally performs linear acceleration and CoD tests (Fernandez-Fernandez et al., 2018; Rouissi et al., 2016). Nonetheless, in real-world game scenarios, its location is very flexible. After decelerating, an athlete may find oneself off balance and forced to accelerate in a new direction (Chaabene et al., 2020; Fiorilli et al., 2017; Paul &

Nassis, 2015; Paterson et al., 2016). While athletes with less muscle mass have lower maximum strength than more muscular and heavier athletes, they may need less force for acceleration and deceleration owing to their total lower body mass as it overcomes Newton's law (Thomas et al., 2017). However, keeping in mind the relative strength contribution as well.

Despite the stride length disadvantage, the shorter player is also more agile in the turns owing to the lower center of gravity. The advantages for small and light-weight players in CoD 5-0-5 may be most evident in "multi-turns" situations, in which there are several turns in a short period (Fernandez-Fernandez et al., 2018; Neil, 2018; Worst et al., 2019). However, such benefits may be lost if fewer turns and longer runs are required instead. Often, a trade-off between strength and agility arises. It is probably incorrect to assert that the characteristics above are only needed for CoD 5-0-5 operation (Dugdale et al., 2020; Worst et al., 2019; Zapartidis et al., 2018). For instance, the elite group's horizontal movements was more significant, allowing them to avoid "wasting" effort on vertical displacement (Dugdale et al., 2020). Without a doubt, reactive force is an essential trait for straight sprints as well.

Deceleration and Acceleration in Sports

Deceleration is frequently used in sports that need a gradual or immediate stop or a reduction in body velocity before a vertical, horizontal, or lateral direction change. When decelerating, the forces applied on the body are highly considered, especially when the period over as the forces must be absorbed is short (Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016; Young & Rogers, 2014). As a result, proper technique is critical for reducing injury risk, maintaining balance, and successfully transferring accrued elastic energy into succeeding movements (Arpinar-Avsar & Celik, 2020). Successful decelerations have certain kinematic and kinetic characteristics associated with improved performance, that can help strength and conditioning coaches understand how to condition and "cue" athletes to change direction better (Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016; Young & Rogers, 2014). It should be emphasized that the data discussed in this article is based on a combination of empirical data and qualitative interviews with top and semi-elite females (Paterson et al., 2016).

During any sprint performance, irrespective of the relative speed of the sprint, deceleration is necessary to lower the body's center of mass (COM). The time and distance covered to slow the COM are decided by different parameters defined by the sport's specific needs (Arpinar-Avsar & Celik, 2020). Touch rugby, netball, basketball, soccer, and other team sports feature unique boundary lines that constrain several participants to a single area. In such sports, deceleration can respond directly to other players' movements (marking, evading, or avoiding collisions) or staying within the playing area. Players will be expected to decelerate from varied speeds over a range of distances and timeframes in these instances (Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016; Young & Rogers, 2014).

Individual sports, on the other hand (tennis, squash, badminton, and so on), need players to accelerate and decelerate very quickly across short distances, mainly in response to the opponent's shot selection. Regardless of the sport, it is apparent that deceleration has a significant impact on the team and individual player performance (Arpinar-Avsar & Celik, 2020). Thus, there is clear explanation on the differences between acceleration and deceleration in sports, discusses deceleration method qualities essential for the successful and effective execution of these rapid changes in velocity, and briefly describes criteria that should aid in exercise selection to improve deceleration performance.

Force may be produced or created only while the foot is in touch with the ground, the instance leg's duration in the air during deceleration is restricted to allow for more time on the ground. However, the landing leg makes contact with the ground ahead of the COM during the deceleration phase as the horizontal distance between the lead leg and the COM when the foot contacts the ground, opposing the body's forward motion (Figure 1b) (Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016; Young & Rogers, 2014). This is performed by flexing the hips (to a similar angle as at the maximum velocity phase), extending the knee, and plantar flexing the ankle (Arpinar-Avsar & Celik, 2020). To retain maximum ground contact, the foot first hits the ground with the heel like in generating a horizontal braking force, and then swiftly rolls to the forefoot, establishing complete foot-ground contact. On the contrary, during which the forefoot makes contact with the ground first, as shown in, the support phase involves maintaining an elevated heel, for instance, limiting braking forces and increasing propulsive forces. During the acceleration phase, the support foot maintains contact with the ground until the tibia passes ahead of the ankle's vertical axis, enabling the legs to absorb a higher amount of negative effort (Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016; Young & Rogers, 2014).

During the deceleration phase, the body's posture is modified to allow for the absorption and distribution of the significant eccentric forces throughout the body (Düking et al., 2016). Different body segments are modified compared to the acceleration phase to decelerate the forward-moving COM (Düking et al., 2016; Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016). The forward lean during acceleration permits the body to be positioned for larger horizontal propulsive forces during deceleration since the body's momentum must be diminished. During deceleration, the torso takes a more upright posture (in proportion to the lower body and posterior lean, relocating the COM posterior to the support base, resulting in increased horizontal braking forces (Düking et al., 2016; Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016). Immediate knee and hip flexion and ankle dorsiflexion occur upon landing, diffusing impact forces over many joints (Düking et al., 2016). This reduces the stress by enabling the muscles to do more negative work or applying pressures throughout a more extensive eccentric range of motion.

Thus showing, clear differences on impact, range of motion, forces, muscle contraction and footwork between the acceleration phase compared to the deceleration phase. However, no such distinctions in the scientific literature are addressed during measurements of CoD abilities in overall time. Clearly demonstrating a need to assess specific phases during test such as the 505, Illinois, TriT and the like. Giving unique information that can help detects distinct changes during CoD movements, to help uncover injury risk, improved abilities and improvement areas.

Concentric and Eccentric Muscle Contraction

Tension is generated in muscle fibers via actin and myosin cross-bridge cycling. When a muscle is under strain, it might extend, shorten, or retain the same length. Although the word contraction indicates shortening, it refers to muscle fibers creating tension with the assistance of motor neurons when applied to the muscular system (Neil, 2018; Worst et al., 2019). There are different kinds of muscular contractions described by the changes in the muscle's length during contraction. Isotonic contractions sustain consistent muscular tension during the muscle's length change (Düking et al., 2016; Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016). This may occur only when the peak force of contraction of a muscle surpasses the muscle's entire load. Isotonic muscular contractions may be concentric or eccentric.

A concentric contraction is a form of muscular contraction in which the muscles contract and shorten simultaneously with the generation of force (Arpinar-Avsar & Celik, 2020). This is a characteristic of muscles that contract by the sliding filament mechanism, and it happens throughout the muscle. As a result of the sliding filament mechanism, such contractions also modify the angle of the joints to which the muscles are connected. This happens throughout the muscle's length, producing (Arpinar-Avsar & Celik, 2020; Teo et al., 2016; Young & Rogers, 2014). For example, when the hand goes from near the knee to around the shoulder, a concentric contraction of the biceps will force it to bend at the elbow. A concentric contraction of the triceps alters the angle of the joint in the opposite direction, straightening the arm and bringing the hand closer to the leg.

On the contrary, eccentric contractions result in muscular elongation. These contractions slow down the muscle joints (serving as "brakes" for concentric contractions) and shift the load force's location. Voluntary and involuntary contractions are also possible. During an eccentric contraction, the muscle lengthens while under stress due to an opposing force larger than the muscle's force (Düking et al., 2016; Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016). Rather than pulling a joint in the direction of the muscle contraction, the muscle operates to slow the joint down towards the conclusion of a movement or otherwise manage the repositioning of a load. This may happen automatically (when trying to raise a weight that the muscle is incapable of lifting) or consciously (when the muscle is "smoothing out" a movement) (Neil, 2018; Worst et al., 2019). Strength training that incorporates both eccentric and concentric contractions seems to build muscle strength more than concentric-only training in the near term.

Several previous studies have shown connections between strength and power and leaping performance utilizing a range of testing methodologies, including isometric tests, multijoint dynamic tests, and isokinetic dynamometry. Worst et al. (2019) discovered an excellent correlation between peak force (PF) in an isometric midthigh pull (IMTP) and vertical jump (VJ) performance and between 1RM (1 repetition maximum) squat and VJ performance in recreationally trained males. Worst et al. (2019) found significant relationships between relative 1RM squat and power clean body mass) peak power (PP), close countermovement jump (CMJ), peak velocity (PV), and relative countermovement jump (CMJ) height in male college athletes. They found no association between the CMJ and measures of absolute strength (1RM squat, power clean, isometric squat PF, or IMTP PF. Dugdale et al. (2020) discovered a moderate link between relative power clean and squat performance and CMJ performance in top volleyball players. Dugdale et al. (2020) found the highest link between absolute strength and CMJ height in well-trained young soccer players during a projected maximum squat test. Düking et al. (2016) noted a relatively good connection between isokinetic concentric knee extensions and VJ performance when utilizing isokinetic dynamometry (Moya-Ramon et al., 2020). According to these data, it seems as if increasing lower-body strength might benefit athletes seeking to improve their leaping prowess.

Utilizing the stretch-shortening cycle (SSC) during dynamic exercises such as the CMJ resulted in improved performance compared to a squat jump without an SSC component (3 to 5 cm in maximum jump height Teo et al., 2016; Young & Rogers, 2014). The SSC begins with an eccentric muscle stretch, leading to increased force output during the succeeding concentric phase. Previously, one of the causes of this increased force output was increased cross bridges, which acted as a catalyst for the succeeding concentric phase (Düking et al., 2016). Because eccentric strength is mechanical and thus a function of the number of cross-bridges formed, it is proposed that increased levels of lower-body eccentric force may also result in increased cross-bridge potentiation and thus enhanced performance in SSC activities such as the CMJ. Despite this, relatively little research has been conducted to examine the association between eccentric PF and jumping performance.

An isokinetic device (Exerbotics squat) with a load cell was recently utilized to determine an individual's concentric and eccentric PF (Teo et al., 2016; Young & Rogers, 2014). Thus, the goal of that experiment was to explore the connections between concentric and eccentric PF (absolute and relative) and CMJ performance in resistance-trained males using the Exerbotics squat apparatus. If a link between lower-body eccentric force output and CMJ performance could be established, lower-body eccentric strength training may be included to improve an athlete's jumping ability (Düking et al., 2016; Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016). The hypothesis was that there would be a strong association between eccentric force (absolute and relative) and CMJ performance.

Vertical and Horizontal Movement

Vertical loading refers to resistance and effort parallel to the body, for instance, a back squat, Olympic style lifts, or a deadlift. In contrast, horizontal loading relates to resistance and effort perpendicular to the body. Certain loading patterns may be less transferrable to the high-level athlete, according to research Teo et al., 2016; Young & Rogers, 2014. Upon examination of the accompanying statement, it seems to be rather broad. Although both loading strategies increased leisure performance, top-level athletes (national level or above) failed to exhibit gains in a battery of tests. The research examined three vertical loading workouts and their associated benefits and drawbacks.

When planning or conducting training sessions, the primary concern is the ability of gains to be transferred to the playing field. Researchers are discovering that high-level athletes may lack the ability to transmit vertical loading activities (deadlift, squat, and O-lifts). While experts agree that strength training enhances muscle's capacity to generate force, they are dubious to whether this benefit applies directly to top athletic performance. Training must be as precise as possible to be successful. One research examined the effect of particular and non-specific training techniques on sprint performance in leisure and elite-level athletes to see if specificity had a role in performance improvement ((Helme et al., 2019; Kaur & Sinha, 2020; McFarland et al., 2016; Neil, 2018; Raya-González et al., 2020; Sawczuk et al., 2016). While non-specific training was practical for leisure athletes, special training was most effective for top athletes. Although data seems to confirm the intuitive reasoning that sport-specific training is more beneficial, something surprising occurred (Düking et al., 2016; Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016). For instance, elite rugby and soccer players were trained for a year utilizing vertical loading strength training techniques. Although strength increased, sprint timings and CoD remained the same. Both of these are crucial components of their respective sports, yet none seemed to improve. They discovered that even a minor improvement in sprint speed required a significant improvement in 1RM Back Squat (20 percent) (Liu et al., 2020). A significant rise in 1RM is challenging to accomplish and, regrettably, unrealistic for athletes at elite levels.

Numerous research investigations have indicated that applying force horizontally has a stronger effect on and correlation with sprint speed. For instance, wide leaps, hip thrusts, lateral jump training, and kettlebell swings stimulate the muscle required to extend the hip more than vertically loaded movements (Helme et al., 2019; Kaur & Sinha, 2020; McFarland et al., 2016; Neil, 2018; Raya-González et al., 2020; Sawczuk et L., 2016). Unfortunately, the research has not resolved all of the jigsaw pieces, and in practice, it is difficult to decide which way of loading is preferable. However, it can be assumed that during horizontal loading activities, the muscles most active during strong hip extension (glutes and hamstrings) are more active. The researcher attributes strong hip extension to enhanced sprinting, lateral bounding action and importantly CoD

As previously stated, the study can only infer that improved sprint speed and vertical leap height result from maximum hip extension (Düking et al., 2016; Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016). Horizontal loading seems to stimulate the muscles involved for hip extension more than vertical loading. According to the complexity of athletic movement, horizontal loading appears to be more transferrable (Liu et al., 2020). Precisely, be as sport-specific as possible to maximize training impact. Hence, a balance of both sorts of loading seems to be the most suitable. Although studies indicate that transfer is modest, the increased load intensity associated with vertical workouts increases the strength required to generate higher amounts of force (Düking et al., 2016; Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016). Combine this with horizontal loading to get the force transfer application. Although training specialization is the optimal method, it seems to be optional for elite level. General work should emphasize athletes who lack sufficient strength and conditioning or weight lifting expertise. If an athlete lacks fundamental movement abilities or proper posture during exercise, thorough training will be ineffective. Maintaining a basic approach and improve as required to ensure the athlete's safety throughout contests.

Chapter Summary

Agility has long been seen as a necessary component of athlete performance, particularly for team sport athletes (Helme et al., 2019; Kaur & Sinha, 2020; McFarland et al., 2016; Neil, 2018; Raya-González et al., 2020; Sawczuk et L., 2016). However, most research has failed to define the proper distinctions between different phases of the CoD and agility. Numerous writers have defined agility as the capacity to shift directions quickly and with a minor loss of movement speed in response to external cues ((Helme et al., 2019; McFarland et al., 2016; Neil, 2018; Raya-González et al., 2020; Sawczuk et L., 2016). This skill is critical for players participating in team sports to escape or acquire positional advantages during game circumstances. On the other hand, preplanned motions with rapid direction changes, often known as CoD, play an equally significant part in gaming settings (Kaur & Sinha, 2020; McFarland et al., 2016; Neil, 2018; Raya-González et al., 2020; Sawczuk et L., 2016). CoD is defined explicitly in this research as the capacity to accelerate from a standing posture, decelerate, and reaccelerate before changing direction (Kaur & Sinha, 2020; McFarland et al., 2016; Neil, 2018; Raya-González et al., 2020). Although most strength and conditioning programs focus on increasing athletes' lower body strength and power performance, relatively few researchers have examined the transfer and relationship between different types of movements and CoD (McFarland et al., 2016; Neil, 2018; Raya-González et al., 2020; Sawczuk et L., 2016). Inconsistent findings from prior research may be attributed to disparate assessment techniques (overall time), subject backgrounds, training modalities, and duration of the training intervention.

Jumping and running are often employed to determine if the capacity to produce large forces is a constraint on CoD. Dynamic strength, more precisely relative back squat strength (back squat/BW), has also been implicated in sprint and CoD performance. However, the fundamental processes behind the relationship between lower body strength characteristics and CoD performance remain unknown because of a shortage of studies. This research may establish a link between the particular CoD test and different types of movements. As a result, straight-line running and other lower body strength and power parameters from loaded and unloaded vertical and horizontal jumps were investigated to determine their associations with both overall time CoD and phase specific CoD (initial acceleration to deceleration and re-acceleration) This research will assist coaches and strength and conditioning coaches in developing their programs with a scientific basis. Finally, the findings of this study will be helpful for future research.

CHAPTER THREE

RESEARCH METHODOLOGY

This research aimed to conduct a cross sectional study in cooperation with Norways U-21 national team in Handball. Before collecting any data, the aim, methodological approach, storage, and use of data for this research were authorized by the Local ethics committee and Norwegian Data protection agency (NSD). The next chapter discusses the methodology followed during the research process. This covers the design, ethical concerns, the selection of cases and participants and the gathering and analysis of data.

Research Design

This quantitative cross-sectional study attempted to better understand the physical phenomenon through in-depth analysis and interpretation of the events and significant relationships that make up CoD.

Ethical Considerations

Generally, ethical concerns play a crucial role in any research study. Each participant was informed about the study's goal, confidentiality, and their participant rights. The participants volunteered for the research and were told that they might withdraw at any moment without suffering any penalties. Before the study's commencement, each participant completed a written permission form (Appendix 1). To safeguard the participants' privacy, any identifying data acquired through ciphers was instantly anonymized. This is to ensure the confidentiality of all participants. The encryptions were stored separately from the rest of the data set in a CoD file. Thus, no identifying individuals or metrics were included in the transcripts. Data processing happened on an institution-owned computer to which only the student and supervisor had access.

Any participant wanting to view their entire transcripts or get insight into the process did so without restriction.

Additionally, the researcher adhered to a set of ethical study standards. In conjunction with a well-written informed consent, this strategy representing a reputable research institution and working with the Norwegian Olympia was critical for building confidence. Following data gathering, the emphasis should not be simply on the meaning of the knowledge but also its advancement (Chaalali et al., 2016). Because the analytic process is filtered via the scientist's discernments, personal perceptions and interpretations will influence the results. Walts et al. (2021) stated that the methodological approach must be transparent and open; only this will guarantee that findings stay credible and enable the reader to assess if the results represent contemporary reality. As a result, the researcher tried to give an instructive and open description of the procedures followed to generate meaningful and pertinent information.

Data Collection

The data was collected as part of the pre-season test battery for the under 21 Norwegian national teams in handball. 15 male elite handball-players completed a battery of tests consisting of two linear unloaded sprints (20m), the modified 505 test with two left and right foot turns from a two-point start, prior to five left and right unilateral lateral jumps, 5 countermovement jumps (CMJ) and leg press (LP). Both CoD and lateral jumps were performed with a 3kg external load provided by a motorized resistance device (1080 Sprint, 1080 Motion AB, Lidingö, Sweden), CMJ was conducted on force platform (Musclelab; Ergotest AS, Porsgrunn, Norway), whilst leg press and sprint were determined using pneumatic resistance device (Keiser Sport, Fresno, CA) and photocells respectively. The dynamic warm-up consisted of 10 minutes of mild running, ten stationary body weight squats, a 10m walking lunge, and dynamic hip, thigh, and calf stretches, as well as a familiarization of all tests at 50-75% of max. Between 5-10 minutes of rest was implemented between each test to have adequate recovery, and athletes were offered drinks (water) during testing sessions. Overall time was used as outcome measurement for both sprint and the m505 test with the additional phase specific times (phase 1a initial acceleration to deceleration and phase 1b re-acceleration). From the leg press average concentric power (LP avg_power) was calculated, while both concentric peak (CMJ con_peak_power) and average power (CMJ con_avg_power) as well as peak eccentric peak power (CMJecc_peak_power) was calculated from the CMJ data. Relationships between test outcome measurements were determined using correlational analysis (Pearson r) with a significance level of $p<0.05$. All tests and equipment's have previously been showed reliable for measurements. Both LP and CMJ measured by pneumatic resistance device and force plate has been proven to have acceptable reliability (CV:4.2-10.8%, ICC:0.74-0.98) (Lindberg et al., 2020). Similar results have also been shown for lateral jump and the modified 505 using motorized resistance device (CV:3.7-6.9%, ICC: 0.73-0.85) (appendix 2)(Westheim et al., 2020 [manuscript in preparation]).

Change of Direction (CoD) Test

The athletes' CoD performance was evaluated using a modified 505 CoD test. Athletes were instructed to sprint five meters, turn 180 degrees, then sprint back to the starting line. The 1080 sprint machine was located 5 meters away from the turning area (total of 10 meters from starting point) at 100 centimeters height (approximate hip height). The fiber cord was attached to the waist using 1080 sprint belt (1080 Sprint, 1080 Motion AB, Lidingö, Sweden) . Phase 1a of the CoD was conducted with the machine directly in front of the athlete, assisting (3 kg) in the movement. As the turn occurred and phase 1b was underway the machine would then end up directly behind the athlete, resisting (3 kg) the movement. Each athlete completed two familiarization trials at about 50% and 75% of perceived maximum effort, respectively, to reduce the perceptual and decision-making component of the actual trials (Kaur & Sinha, 2020; McFarland et al., 2016; Neil, 2018). Four tests were conducted (two with the left leg and two with the right leg), with a minimum of 2 minutes between each test. The average of the best left and right performance was then used as the measured variable.

Countermovement Jump

Countermovement jumps were performed to determine the athletes' abilities to preform force production vertically. Each athlete completed two familiarization trials at about 50% and 75% of perceived maximum effort, respectively, to reduce unfamiliarity to the test. A minimum of 3 attempts were made on the force platform (Musclelab; Ergotest AS, Porsgrunn, Norway). If the athlete increased peak power on the final attempt compared to previous results, initial attempts were implemented, until a decrease in power was evident. The best results was then used for further analyses. s

20- meters Sprint

The 20-meter sprint test was used to determine an athlete's acceleration capability. Before the straight sprint test, two submaximal 20m sprints at 50% and 75% of maximum effort were used as the last portion of the warm-up exercise. Following a three-minute rest period, each participant completed two trials of twenty-meter straight-line sprints. Sprints were alternated with roughly a two-minute rest period between tests. The test was conducted in a staggered stance, with the front foot 0.5m behind the starting line. 4 sets of timing gates, five meters apart, were put up to record competitors' acceleration times.

Leg Press

For LP the Keiser Air300 horizontal pneumatic leg press with an A420 force and velocity measuring devise was used (Keiser Sport, Fresno, CA). The test was performed with a stepwise increase in load. The lightest starting load was corresponding to approximately 15% of 1RM. Gradually increasing the load in a fixed manner (20-30 kg), until reaching the approximant 1RM, and a total of 10 attempts were conducted. This was done in accordance to prior research done by Lindberg et al. (2020). Total amount of rest between reps increased in conjunction with the load. With 10-20 sec rest during the 5 first load, and 20-40 seconds for the final loads.

Lateral jumps

Lateral jumps were performed to determine the athletes abilities to preform horizontal force production. The 1080 sprint machine was located 5 meters away from the jumping area at 100 centimeters height (approximate hip height) perpendicular to the athlete. The fiber cord was attached to the waist using 1080 sprint belt (1080 Sprint, 1080 Motion AB, Lidingö, Sweden). Each athlete completed two familiarization trials at about 50% and 75% of perceived maximum effort, respectively, to reduce unfamiliarty to the test. A minimum of 5 attempts were made on each leg, whilst starting leg (L vs R) was randomized beforehand. If the athlete increased peak power on final attempt compared to previous results, initial attempts were implemented, until a decrease in power was evident. The lowest and highest values for both legs were erased, and the average was then used for further analyses.

Variable	Definition
m20	Time spent on the 20-meter sprint
CMJPeakPowerCon	The Peak power of the CMJ in the concentric phase
CMJPeakPowerECC	The Peak power of the CMJ in the eccentric phase
CMJAVGPowerCon	Average Power for the concentric phase in CMJ
KeiserAVGPower	Average Power of left and right leg for the Keiser test
AVG505	Average time of left and right turn for the 5-0-5 CoD
AVG1a	Average time of left and right turn for phase 1 (first 5 meters. The part that incorporates deceleration)
AVG1b	Average time of left and right turn for phase 2 (Last 5 meter. The part that incorporates reacceleration)
LaterjumpAVGPower	Average Power of left and right leg for the lateral Jump test
LateralJumpAVGSpeed	Average Speed of left and right leg for the lateral Jump test

Assumptions

The characteristics of these handball players are presumed to reflect similar athletes at these levels, and that results from this study can to some degree be used to generalize for similar athletes. In addition, every participant has not been impacted by injuries and has made maximum efforts throughout sprinting,, LP, vertical and horizontal jumping, and CoD testing, as is expected.

Data Analysis

The individual variables were acquired from the velocity and average force/power when there was a concentric phase of the motion. For every incremental loading test, a separate linear regression was fixed with speed, force, and time as the dependent variables and regressed against individual's countermovement jumps (CMJ), power average, and lateral jump power as the independent variables to the velocity and average force measurements to estimate and extrapolate the individual variables (Walts et al., 2021).

Variables obtained from the force plate were analyzed using Ms Excel Spreadsheet. Velocity was obtained as an integral of acceleration from gravitational forces. The center of mass position was calculated by integrating velocity, whereas power was obtained by multiplying velocity and force. In the case of the CMJ, the velocity integration began due to the pressure falling below five standard deviations of the steady-stance weight. Moreover, the concentric phase was described as the point where velocity was more significant than 0 m/s. As a result, the concentric phase for CMJ was known as the prompt as the participant fail to use the force plate.

Average speed, power and time achieved at a given load (3 kg) during lateral jump and CoD was calculated using the velocity curve that was generated by the 1080 Sprint software. All data was thereafter extrapolated to Ms Excel Spreadsheet for further analyses. 1080 sprint setup is shown in appendix 3

Statistical Analysis

Table 1 below shows the sample Pearson's correlation coefficient (r) values. As seen from the table, values can range from $-1\ to + 1$ where the greater the absolute value of the Pearson's correlation coefficient, the stronger the relationship between two variables. The sign of the r represents the direction of the relationship with positive r, indicating that when the value of one variable increases, the value of the other variable also tends to increase. Negative r values show that when the value of one variable increases, the value of the other corresponding variable decreases. The study considers the Pearson's correlation coefficient, r as standard effect size since they indicate the strength of the relationship between FV-variables using unitless values between a standardized range of $-1\ to + 1$. The researcher included the p-values at 95% and 99% significance levels to test the null hypothesis that there is no linear relationship between two variables $(r = 0)$ visa s. The alternative hypothesis is that there is a linear relationship between two FV-variables $(r \neq 0)$. If the $p - value$ is less the significance level at 95% or 99% significance level, we reject the null hypothesis and conclude that the correlation coefficient $(r \neq 0)$ In comparing the methods, the mean difference was determined in both relative and absolute terms with standardized and percentage difference divided by the standard deviation of variable (Chaalali et al., 2016). The standardized variance was qualitatively analyzed using the scale, and the significance level of the variation in means was tested using t-test paired samples. However, the averages of the two both leg testing time/speed points were used when comparing across methods.

Evidence of Trustworthiness

The researcher established the reliability and validity of the data gathered and evaluated it through credibility, transferability, dependability, and confirmability. As a consequence, it enhanced the findings' authenticity and validity.

By verifying the findings, the study validated the results of the data gathered and evaluated. The researcher used reflexivity principles to ensure the study's confirmability. Reflexivity steered scholars toward a technique of reflection that is exhaustive, relational, and realistic. The researcher was required to disclose one's status as a former elite soccer player who participated in the Norwegian Soccer Team of professionals in Australia. The three facts may have introduced unintentional bias into the data collection process by organizing, coding, evaluating, analyzing, scrutinizing, and interpreting it. Therefore, the researcher demonstrated confirmability by identifying any potentially unfavorable results.

CHAPTER FOUR

RESULTS

Correlation Analysis of the FV-variables

The section presents the Pearson's correlation coefficient statistics, r, indicating the strength and the linear direction of the relationship between different FV variables. The correlation coefficient was used to quantitively assess both the direction and strength of the variables that make up both vertical and horizontal mvements (m20, CMJPeak PowerCon, CMJPeak PowerECC, CMJAVG PowerCon, KeiserAVGPower, AVG505 AVG1a, AVG1b, LaterjumpAVGPower, LateralJumpAVGSpeed) tend to vary together. In total 15 male elite national level hand ballplayers took part in the study (age 21±1.6 years, height 192±6.5 cm, body weight 96 ± 10.8 kg)

Table 1

Relationship between variables

Correlations	**m20**	**CMJPeak Power Con**	**CMJPeak Power ECC**	**CMJ AVG Power Con**	**KeiserAVGPower**	**AVG 505**	**AVG1a**	**AVG1b**	**Lateral JumpAVGPower**	**Lateral JumpAVGSpeed**
m20	1	0.15	0.48	0.22	0.25	0.32	0.1	.77**	-0.44	-.52*
CMJPeakPowerCon	0.15	1	-0.11	.97**	.89**	.54*	.58*	0.21	0.13	0.39
CMJPeakPowerECC	0.48	-0.11	1	-0.02	0.06	0.05	-0.06	0.27	-0.5	-0.42
CMJAVGPowerCon	0.22	.97**	-0.02	1	.93**	.6*	.61*	0.28	0.07	03
KeiserAVGPower	0.25	.89**	0.06	.93**	1	.73**	.72**	0.34	-0.04	0.2
AVG505	0.32	.54*	0.05	.59*	.73**	1	.96**	.56*	-0.28	-0.06
AVG1a	0.1	.58*	-0.06	.61*	.72**	.96**	1	0.33	-0.20	0.08
AVG1b	.77**	0.21	0.27	0.27	0.35	.56*	0.33	1	-0.39	-0.49
LaterjumpAVGPower	-0.44	0.13	-0.5	0.07	-0.04	-0.28	-0.2	-0.39	1	.8**
LateralJumpAVGSpeed	-.52*	0.39	-0.42	0.3	0.2	-0.06	0.08	-0.49	.8**	1

$**$ indicate $p < 0.001$ $*$ indicate $p < 0.05$. colored box indicates absolute r, $|r| \geq 0.5$

From table 1 above, time spent on the 20-meter sprint ($m20$) tends to increase as the average time for left and right turn for phase 1b (the last 5 meters) increases ($r = 0.769$). The relationship is significant at a 99% confidence level. The evidence supports the nation that there is a positive relationship between the time spent on the 20-meter sprint and the average acceleration time in the last 5 meters. However, time spends on the 20-meter spent is found to be weakly associated with the average time for the left and right turn for phase 1a ($r = 0.098$). On the other hand, the Average Speed of the left and right leg for the lateral Jump test was negatively correlated with the time spent on the 20-meter sprint (2.83±0.11s) ($r = -0.522$) and is significant at a 95% confidence level. As the average time for the left and right leg for the lateral jump test increases, the time spent on the 20-meter sprint decreases However, overall sprint time showed neither with phase 1a (r= .10, p>0.05) nor overall time 505 (r= .32, p>0.05). Furthermore, Phase 1a had stronger correlation with overall time on the m505 test (r=.96) compared to phase 1b (r= .56, p<0.05), but the different phases did not correlate with each other (r=0.33, p>0.05). Average max speed for the lateral jump tests (2.86 ± 0.18 m/s) had a stronger correlation with 1b compared to 1a (R=-0.49 vs 0.09). Result from CMJ (Peak concentric: 5282 ± 795 Watt, Peak eccentric: 2111± 589 Watt, Average concentric: 2936± 429 Watt) and Keiser (1142 ± 169 Watt) did not show significant correlation with neither 20 m sprint (R=0.15, 0.48, 0.22 and 0,25 p>0.05 respectfully) nor phase 1b (R=0.21, 0.27, 0.27 and 0.35 p>0.05 respectfully). However, $CMJ_{con\_peak\_power}$, $CMJ_{con\_avg\_power}$ and LP did show significant correlation with both overall time of 505 (R=0.54, 0.59 and 0.73 p<0.05) and phase 1a (R=0.58, 0.61 and 0.72 p<0.05)

CHAPTER FIVE

DISCUSSION

Correlation Between CoD, Vertical Jump Power, and the 20-meter Sprint Performance

Consenetric vertical jump characteristics (CMJPeak PowerCon and CMJAVG PowerCon), which were used to quantify the players' lower body power, were significantly associated with CoD overall time (r = 0.54 and 0.59, p 0.05) and phase 1a (r = 0.58 and 0.6, p <0.05) performance. Prior research (Castillo-Rodrguez et al., 2012) found similar findings. Vertical leaps, particularly static jumps, begin with athletes in a squatting posture comparable to the transition period between deceleration and re-acceleration motions. Additionally, significant to very high correlations between Keiser and CoD performance (Overall time and phase 1a) were discovered (r = 0.73 and 0.72, p< 0.01). These findings seem to corroborate those of Chaouachi et al. (2012). It should be emphasized that CMJs and SJs most likely reflect somewhat different processes for power production in muscular systems (Stone et al., 2007), and more research is necessary to elucidate the distinct underlying mechanisms underpinning CoD tasks and vertical leaps.

This research discovered low correlations between the 20 m sprint and vertical jump characteristics (r = -0.15 to 0.48 p>0.05). These findings are somewhat contradicting to prior research (Chaabene et al., 2018). Due to the short stretch-shortening characteristic of running, investigations often utilized CMJs due to the muscular contraction pattern similarities (Chaabene et al., 2018). The findings contradict Dos'Santos et al. (2017), who discovered that the CMJ is the most significant predictor of sprint and CoD test performance. However, it should be emphasized that their research included female volleyball players at the NCAA Division I through Division III levels. Additionally, CMJs is the most often used leaping action in volleyball matches (Chaabene et al., 2018; Dos'Santos et al., 2017; Nimphius et al., 2018). This movement specificity may explain the disparity in predictability for CoD performance across sports, and that correlations between dynamic strength and CoD performance are sport and population-specific.

These findings show that although the participants' capacity to use the eccentric phase was decreased during the recovery phase, specific compensatory actions during the jump execution seemed to mitigate the decreases in jump height and power generation. Furthermore, following the strength-oriented session, the reduction of eccentric peak force seemed to be associated with a slower eccentric phase during the CMJ. For instance, increased eccentric time since the center of mass was not lowered. On the contrary, it seemed as if participants lowered their center of mass more after the power-oriented exercise than before, particularly after 48 hours. Future research should examine how the kinetics and kinematics (movement strategies) of a CMJ vary during the recovery and rest states (Kadlubowski et al., 2019). However, the researcher proposes that eccentric peak force is a more sensitive indicator of tiredness and neuromuscular deficits than jump height or maximum power.

Correlation Between Linear Sprint and COD Test

During the COD test, the correlations between CoD and phase specific attributes were very strongly correlated ($r = 0.56$ and 0.96 $p < 0.05$ and $p<0.001$). These findings indicate that individuals who accelerate more rapidly within the first meters and decelerated at a faster past were more likely to complete the CoD test in a shorter period. However, due to the incorburation of both phases in the total CoD, it is somewhat explanatory for the higher correlation. However, the findings that phase 1a had a more robust correlation can suggest that these asbects are more critical for the total time. Intrestingly the phase specific attributes did not show a significant correlation with eachother, which can be a sign of different muscular contributions between the two. Additionally, connections established showed a correlation between COD variables and 20m sprint ($r = 0.32$, $p>0.05$), AVG1a ($r = 0.1$, $p>0.05$) and AVG1b $r = 0.78$, $p<0.01$) respectively and vice versa. With a much higher, and significant connection with phase 1b. Indicating that some transfer effects from COD to the 20m sprint, with higher effects to phase specific aspect (1b) of the CoD. On the other hand, Paul and Nassis (2015) revealed contrary findings, just a little variation in common (r) between the 20m sprint test and the COD testing in athletes who compete in professional soccer. The inconsistencies in the results may result from the various CODs, as shown in Table 1. performance of linear sprint and CoD in the strong and weaker groups (mean standard deviation).

During the study, participants performed one COD movement; the Linear test asks athletes to do COD movements to accomplish the assignment. To investigate the relationships between these two critical concentric and eccentric power in soccer groups via the development of CoD tests are better tailored to the needs of soccer matches, such as the work-to-rest ratio and the number of COD are required. This shows the importants of validating the numerous CoD tests in the scientific world, and that many of these tests can have contradicting muscular contributions, and in effect measure a multitude of abilties.

Correlation Between Vertical Movement and Horizontal Movement

The vertical movement (KeiserAVGPower) and CMJAVGPoweCon ($r=0.73$, $p< 0.001$ and 0.59, $p < 0.05$), have strong correlation with CoD overall time, but shows non significant correlations with phase specific attributes (1b). However, the horizontal jump movements (LateralJumpAVGPower) and (LateralJumpAVGSpeed) is ($r=-0.52$, $p<0.05$), which is significantly correlated with m20. In contrast, the horizontal jump (LateralAVGPower) $r= 0.43$, $p>0.05$) has a weaker, non significant correlation with 20-meter sprint. It indicates that phase specific assessment of m505 tests provide unique information not quantified by tests such as the 20 meter sprint, as well as vertical and horizontal jumps. These findings are somewhat related with (Sayers, 2015; Suarez-Arrones et al., 2020; Teo et al., 2016; Tramel et al., 2019; Zapartidis et al., 2018), where they denoted that athletes were required to press against the ground and produce forces in a maximal effort in order to obtain maximum acceleration during the leap. Thus, vertical jump height and horizontal movement were contingents upon an athlete's capacity to generate large forces in a short period (Suarez-Arrones et al., 2020; Teo et al., 2016; Tramel et al., 2019; Zapartidis et al., 2018). Generally, increased strength levels are correlate with increased CoD rates (Sayers, 2015; Suarez-Arrones et al., 2020; Teo et al., 2016; Tramel et al., 2019). This mechanism may also account for some of the same result in this research, where the horizontal movement was required for vertical jump performance. Two studies included male Australian Rules footballers, one tough rugby league, one involved basketball, and one involved female netball players—three of these investigations utilized a video-based representation of an attacker to give the required stimulus for evaluating agility (Chaabene et al., 2018; Dos'Santos et al., 2017; Nimphius et al., 2018). In contrast, the others used a live tester who executed side-steps like escaping a defender. Pearson coefficients of $r=0.68$, $r=0.321$, $r=0.44$ and $r=0.80$, and a Pearson's correlation of $p>0.05$ were obtained when the agility and CODS tests were correlated (Dos'Santos et al., 2017).

Additionally, the findings of this research indicate that care should be used when inferring improvements in one ability in sprinting) as a result of an improvement in another, for instance, jumping. The concordance between the amplitude and direction of the mechanical outputs measured and the athletic discipline and level at which it is performed demonstrates this uniqueness. When examining the existing literature in light of the present findings, it is worth noting that precisely those studies that found a strong relationship between "horizontal" and "vertical" performances either tested low-level athletes or did not sub-categorize the tested populations by gender, level of practice, or age league (Chaabene et al., 2018; Dos'Santos et al., 2017; Nimphius et al., 2018). In this respect, the findings indicated that when the data were not sub-categorized, there were usually stronger correlations between the vertical profile and the performance variables (SJ height and sprint time to 20 m). This obviously highlights the issue of "transfer" between strength training and sprint performance, particularly in highly trained and experienced athletes. The current findings are the lower the level and homogeneity of athletes' groups, the stronger the connection between horizontal and vertical profiles) indicate that research conclusions should be taken cautiously in light of the populations tested's level and homogeneity. It is not appropriate to generalize results from diverse low-level groupings to higher-level populations.

Correlation Between COD, Acceleration, and Deceleration

Furthermore, Phase 1a had stronger correlation with overall time on the m505 test ($r=0.96$, $p < 0.001$) compared to phase 1b ($r= 0.56$, $p<0.05$), but the different phases did not correlate with each other ($r=0.33$, $p>0.05$). Different body segments are modified compared to the acceleration phase to decelerate the forward-moving COM (Düking et al., 2016; Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016). According to (Düking et al., 2016; Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016), forward lean during acceleration permits the body to be positioned for larger horizontal propulsive forces during deceleration since the body's momentum must be diminished. The findings of the present study, during the deceleration phase, the torso takes a more upright posture (in proportion to the lower body and posterior lean, relocating the COM posterior to the support base, resulting in increased horizontal braking forces with the difference in Phase 1a and Phase 1b. This suggests that there are unique features with different individual athletic measurements, that can potensially be overlooked if the only variable that is quantified is overall time,

These findings emphasize the need to evaluate both jumping, sprinting and phase specific attributes to guarantee a more precise, accurate, and complete description of athletes' physical characteristics, resulting in more effective training regimens. The current research extends extension (Düking et al., 2016; Paterson et al., 2016; Rouissi et al., 2016; Teo et al., 2016)'s findings on poor correlations between certain athletes profile characteristics and leaping and sprinting in top athletes to other sports groups and male athletes. As a result, the approach is expected to benefit both researchers and coaches, as a complete understanding of athletes' characteristics will almost certainly facilitate the subsequent prescription of an effective training program tailored to the athlete's specific needs extension (Rouissi et al., 2016; Teo et al., 2016). While this study addresses several of the significant limitations discussed in the recent literature by (Rouissi et al., 2016; Teo et al., 2016). Consequently, the findings reported here are limited to the assessment period and cannot be generalized to training-induced effects and possible transfer between jumping-type training and sprinting performance (Rouissi et al., 2016; Teo et al., 2016). Numerous studies have been conducted recently to examine the effects of various types of training on either the vertical and horizontal strength, as well as acceleration and deceleration training, and they have demonstrated that both profiles are sensitive to specific resistance training (Chaabene et al., 2018; Dos'Santos et al., 2017; Nimphius et al., 2018). For example, Dos'Santos et al. (2017) recently showed the efficacy of a personalized training program to optimise the athletes' profile in increasing jump performance. Studies in progress will examine the effects of resistance training on both vertical and horizontal movements within subjects to aid in discussing this "training transference" phenomena (Chaabene et al., 2018; Dos'Santos et al., 2017).

After establishing that phase specific CoD are distinct differeabilities, the critical issue is that these abilities are more necessary for performance. The problem may be solved by comparing athletes with higher and lower standards. If a superior-skilled group performs better on a specific test, the test's quality may be considered to be significant for athletic performance (Walts et al., 2021). In contrast, if a higher-level group does not do better on a test, the test's quality seems to have no bearing on more excellent athletic performance. Several studies have shown that the more competent group is superior ($p>0.05$) in an agility test but not in a COD test in the Australian football and rugby league (Chaabene et al., 2018; Dos'Santos et al., 2017; Nimphius et al., 2018). However, as mentioned earlier, measuremnts of only overall time can overlook critical subcomponents that can be key in athletic movement. Various findings demonstrate that agility is more closely linked to success in these invasion sports than COD tests, demonstrating the critical nature of agility's perceptual and decision-making components. This does not however eliminate the need to evaluate athletic performs in CoD, as there can be overlooked phase specific contributions.

Athletes must accelerate efficiently across minimal distances to achieve greater speeds in short times, for instance 5-m (Tous-Fajardo et al., 2016). Therefore, athletes with greater peak speeds are anticipated to perform linear sprints up to 20 m better. However, to accelerate more quickly, significant quantities of strength must be used to overcome this total inertia moment to accelerate more rapidly (Tous-Fajardo et al., 2016). Although many studies have shown the key function of applying horizontal force in sprinting, the consistent study also shows that vertical force generation has a substantial effect on team sport players' speed (Tous-Fajardo et al., 2016).

Therefore, Tous-Fajardo et al. (2016) has recently studied the possibility of achieving a vertical impulse needed to provide appropriate flight times in the sprint acceleration phase, which seems to be linked to maximum velocity limitations achieved by soccer players as opposed to sprinters. The same applies to vertical jump performance, which has been demonstrated to be linked with the ability to quickly generating vertical force and power (Düking et al., 2016). To some degree, these mechanical similitudes justify the presence, in many studies with team-sport athletes, of the tight correlations usually observed between speed and power measures ((Düking et al., 2016). Together, these findings may explain why players with higher speeds are more likely to execute at various speeds and power-related activities better than their slower counterparts.

Furthermore, the 'faster' soccer players also showed more significant CoD deficits on extremely short distances, as has been observed before in other Team sports, for example, rugby and handball) and younger soccer categories ((Düking et al., 2016). It indicates that the sprint momentum and the inertia of these athletes may be less effective in handling their greater approach velocities ((Düking et al., 2016). In consecutive decelerations and accelerations and longer contact periods in CoD boxes, it should be noted that increased momentum is usually related to higher braking and driving forces (Paul & Nassis, 2015). These "biomechanical compensations," in consecutive CoD movements (particularly those at harsh angles like 100°), could potentially influence the entry- and departure speed and reduce the efficiency of quicker (and in this instance stronger) sportsmen to shift their direction (Paul & Nassis, 2015). As a result, professionals with greater maximum acceleration rates tend (in proportion to their linear sprint performance) to lose more time while changing their directions, despite their better success in CoD velocity testing. This can nevertheless be partially explained by the multitude of varying

CoD test, with exemples of longer (20s<), being more biased towards linear sprint than actual CoD (Nimphius et al., 2018)

Nevertheless, CoD losses in boxes that show less aggressive angles where speed preservation is essential (like 45° cutting measures) may be somewhat smaller, even in players with high acceleration rates (Fiorilli et al., 2017; Paul & Nassis, 2015; Paterson et al., 2016). This underlines the important consideration of match movement patterns to develop CoD capability for team sport athletes, particularly those consisting of excentricious exercises, acceleration and deceleration efforts, and special CoD drills, before implementing more comprehensive training approaches (Fiorilli et al., 2017; Paul & Nassis, 2015; Paterson et al., 2016). As well as creating more holistic measuremnents of CoD, to give accurate and valid measurements, such as phase specific attributes. The frequent application of these training activities may increase players' ability to withstand greater approaching speeds, boost their ability to speed up, decelerate and speed up successfully, which appears crucial for increasing CoD efficiency (and reduction of the CoD deficit).

Simply, the findings correspond to prior research literature reports on team sports athletes of various fields and categories (Fiorilli et al., 2017; Paul & Nassis, 2015; Paterson et al., 2016). There was from a broader viewpoint that soccer players with greater maximum rates could leap higher, run higher than their slower counterparts and attain higher CoD velocities. However, it appears to be important that they are less effective in changing direction because they may be linked to their ability to deal with increased input and output speeds or to counterbalance the mechanical consequences of their being faster and more powerful, such as greater inertia (Fiorilli et al., 2017; Paul & Nassis, 2015; Paterson et al., 2016). The cross-sectional design of this research is inherently limiting that does not permit causal conclusions and a control group's absence. Moreover, we have not carried out any bio-mechanical study that might better understand and explain the technical differences between the faster and slower athletes, such as foot contact times and peak bending angles from plant leg and pushing leg when direction changes (Fiorilli et al., 2017; Paul & Nassis, 2015; Paterson et al., 2016). However, this is the first research that shows this problematic relationship in professional handball players. Greater accelerations and decelearation associated with better overall CoD time (Fiorilli et al., 2017; Paul & Nassis, 2015). These results may assist coaches and scientists in developing better and effective training methods in this particular group to enhance CoD performance.

Strength and Power contributions

Generally, strength and power are critical comonents of team sports because they are directly related to straight-line sprinting and CoD performance. According to prior research, the primary main strength is the fundamental basis for power generation in sports (Tramel et al., 2019). Current research results of the recent study, stronger athletes do better than their weaker counterparts in CoD tasks (Tramel et al., 2019). Moreover, the findings of this research corroborated that stronger athletes sprint quicker and scored better on CoD tests (Enright et al., 2018). As a result, athletes who must do explosive actions should include maximum strength training into their strength and physical preparation regimen.

The majority of research has utilized the one-repetition maximum squat to reflect athletes' maximal leg strength. Future research may use agility to investigate the connections between various leg strength characteristics and particular sports motions (Enright et al., 2018). Moreover, the data showed a strong correlation between vertical jumps (CMJs and SJs) and soccer players' CoD and 20-meter sprint ability. Thus, sports scientists and strength and conditioning coaches should include horizontal and vertical leaps into their monitoring plans for complete athletes.

Numerous longitudinal studies have been conducted to enhance CoD performance via resistance training. Because several authors believe that strength and power affect CoD ability, they have developed clear training protocols: heavy lifts, for example, deadlifts, squats, and lunges, Olympic-style lifts, and plyometric (Hojka et al., 2016). These procedures have been shown to improve strength, power, and sprint performance in both athletes and non-athletes. However, none of these trials resulted in an improvement in CoD performance. For example, Hojka et al. (2016) conducted a 15-week strength and power training program with division III American football players in the United States. Neither of the trials demonstrated an improvement in CoD performance when the t-test was used. Hojka et al. (2016) also used Olympic-style lifts in conjunction with strength training or strength exercises alone. Both groups additionally completed CoD and sprint training. For 15 weeks, participants subjected participants to a traditional strength and conditioning program, such as Olympic-style lifts, squats, step-ups, and deadlifts).

In the last five weeks, one group did jump squats utilizing concentric and eccentric contraction stages, whereas another group performed jump squats only using the concentric phase. Both groups also completed a 5-week cycle of agility and sprint training. It is possible that a five-week speed and agility training period may not provide adequate training stimulus to improve CoD timings among division III American football players substantially. Enright et al. (2018) examined the impact of Olympic-style weightlifting and vertical jump training on CoD performance in recreationally active individuals. Participants completed either weightlifting exercises (high pulls, clean and jerk, power cleans, half squat) or vertical jumps (single- and double-leg hops, half squat, drop jumps). There were no substantial improvements in CoD performance recorded. Similarly, Düking et al. (2016) examined the effects of a conventional strength-training program (Olympic-style lifts and strength exercises) combined with plyometric training on CoD performance in Division I volleyball players. The athletes trained for 12 weeks during the off-season and did not enhance their CoD performance substantially (Arpinar-Avsar & Celik, 2020). Arpinar-Avsar & Celik (2020) also examined the effects of a comparable strength and conditioning program on strength-trained men over nine weeks and found no significant changes in CoD performance. Also, Salmela (2018) examined the benefits of a 9-month periodized strength and conditioning program on collegiate female tennis players. It was believed that implementing a periodized strength and conditioning program over an extended period would increase the majority of performance metrics, including CoD.

On the other hand, CoD times rose substantially after the training session (2.8–5.0 percent; impact size 5-0-5. Chaabene et al. (2020) examined the effects of squat-jump training on CoD performance in recreationally active individuals using a modified Smith machine with and without elastic bands. Neither intervention resulted in an improvement in CoD performance. According to the research above, vertical strength and power growth do not necesarly translate to increased CoD performance, as shown by unilateral generation (Düking et al., 2016). However, many attributes may have been overlooked due to the simplicity of unilateral measurements(time). One research, on the other hand found that resistance training in the vertical direction improved CoD performance. Fox (2018) assigned participants to do jump squats at 30% or 80% of their 1RM, which was calculated from the squat exercise for eight weeks (Fox, 2018). This is the only study of CoD training that includes leaping with external weight. Both groups improved substantially in the t-test (after the training session, with the higher group improving the most (Chaabene et al., 2018). Although the jump-squat exercise is done vertically, it is distinct from the previous exercises. When individuals squat, they generate higher velocities and eccentric pressures while their muscles lengthen, comparable to a CoD. An eccentric solid strength foundation, which may be built via jump-squat training, would be required to use these high pressures. Thus, given that strength and power training in the vertical direction may not improve CoD performance, increased eccentric loading/training stimulus may be responsible for the improved CoD performance.

Dos' Santos et al. (2017) found that recreationally active males improved significantly in the shuttle run (6 5 m) after eight weeks of jump training. The individuals completed vertical and horizontal leaps in bilateral and unilateral. CoD times reduced substantially (-3.6 percent; effect size = 2.1) after the training session. Similarly, Tous-Fajardo et al. (2016) found gains in CoD performance after a six-week training regimen consisting of vertical, horizontal, and lateral jumping (unilateral and bilateral). CoD times for the t-test and the Illinois agility test were substantially decreased (-5.5 percent; effect size = 0.6). It is possible that unilateral and bilateral horizontal jump training contributed more to CoD performance gains than vertical jump training. Previous research has shown no increase in CoD performance with vertical jump training alone (Tous-Fajardo et al., 2016). Alternatively, a mix of vertical and horizontal or lateral jumping-type motions is required to enhance CoD ability. The findings of these two studies are promising for athletic populations. They indicate that horizontal and lateral leaping should be studied more extensively in the future, such as training effects and movement mechanisms. Unfortunately, no research has been conducted to compare the impact of horizontal and lateral jump training on phase specific CoD performance to vertical jump training.

Future Implications

Strength and power abilities are critical for elite players because they are directly related to straight-line sprinting and CoD performance. According to prior research, maximum strength serves as the fundamental basis for power generation (Chaabene et al., 2020; Fiorilli et al., 2017; Paul & Nassis, 2015; Paterson et al., 2016). According to this data and the current research results, stronger athletes do better than their weaker counterparts in CoD tasks (Chaabene et al., 2020; Fiorilli et al., 2017; Paul & Nassis, 2015; Paterson et al., 2016). However, phase specific assessment of m505 tests provide unique information not nessecarly quantified measuremnts such as leg press, 20 m sprint and different jumps. Additionally, the findings of this research corroborated the notion that stronger athletes not only leap higher and sprint quicker but also score better on overall CoD tests, even though more holistic attributions may provide better measurements(Chaabene et al., 2020; Fiorilli et al., 2017; Paul & Nassis, 2015; Paterson et al., 2016).

The majority of research have utilized the one-repetition maximum squat to reflect athletes' maximal leg strength. More importantly, please note that our research discovered that CoD and straight sprint performance were not highly related at 333 Hz(Chaabene et al., 2020; Fiorilli et al., 2017; Paul & Nassis, 2015; Paterson et al., 2016). Future research may use IMTP to investigate the connections between various leg strength characteristics and particular sports motions (Chaabene et al., 2020; Fiorilli et al., 2017; Paul & Nassis, 2015; Paterson et al., 2016). Additionally, the data showed a strong correlation between vertical jumps (CMJs) and athletes overall CoD. Thus, sports scientists and strength and conditioning coaches should include IMTP and vertical leaps into their monitoring plans for complete athletes (Paterson et al., 2016).

More imperatively, future studies should be directed to determining the optimum kinetic and kinematic parameters for CoD activities, as well as phase specific contributions. Additionally, longitudinal research using training interventions in various sexes, sports, and training environments is needed. Researchers in this field should compare multiple training methods such as heavy resistance exercises, weightlifting movements, and plyometric exercises conducted vertically in both the short and long term to determine the transfer effects on CoD performance. As a result, it is considered essential that future research concentrate on this subject. Also, future study should place a premium on distinguishing between strength features such as eccentric, concentric, and isometric strength and their correlations with CoD phase specific performance to ascertain the essential strength needs associated with various stages of COD movements (Chaabene et al., 2020; Fiorilli et al., 2017; Paul & Nassis, 2015; Paterson et al., 2016). Additionally, the study should be directed on determining the optimum kinetic and kinematic parameters for COD activities. Additionally, longitudinal research using training interventions in a variety of sexes, sports, and training environments are needed.

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Chapter Summary

Given the limitations, delimitations, and wide range of COD tests and sprint test lengths, the research provided in this section make it difficult to untangle connection between COD and leg strength and power characteristics with a large degree of confidence. It's also worth noting that the strength and significance of a connection have no bearing on whether relationship between two variables is causal. As a result, correlational research has limited use in determining the causal connection between specific factors and COD ability, but should be used as a first step in determining casual effects. Other factors such as body mass, physique, flexibility, technique, and leg strength qualities have diverse effects on statistical models, leading to the conclusion that correlational studies' preoccupation with finding the best strength and/or power predictors of functional performance is fundamentally flawed.

Sport practitioners and academics want to know how different training programs affect the variable of interest, in this instance COD. To accomplish so, longitudinal training treatments must be used to map changes in leg muscle characteristics and straight running speed. It is anticipated that by using this method, those factors that have a significant effect on COD ability will be clarified, giving the reader insight and emphasis on what variables should be evaluated, developed, and monitored.

CHAPTER SIX

CONCLUDING THOUGHTS

Based on the lack of significant correlations between the different performance tests (sprint and CoD), especially for phase 1a, and that there are no significant correlations between phase 1a and 1b, it appears that CoD tests with phase specific analysis provide unique information that might be of important for ball sport athletes. Both leg press and CMJ outcome measurements were correlated with phase 1a and overall m505 time but not with phase 1b and linear sprint performance. Based on current findings it appears that phase specific assessment of m505 tests provide unique information not quantified with CMJ, leg press, lateral jump or linear sprint tests which can be important to performance in ball sport athletes. However, further research should compare the impact of field-based training versus video-based instruction as these tests were purely pre-determined.The current experiment did not examine answer accuracy, reaction time, or decision time. As a result, more research into these factors is necessary.

One of the study's weaknesses was that it did not account for the influence of participants' laterality. It is noted that young top soccer players performed better with the dominant leg than with the non-dominant portion when it came to CoD (Zapartidis et al., 2018). Therefore, future research should evaluate the influence of laterality when comparing various training groups. Notably, CoD 5-0-5 skill has little bearing on soccer play, even though coaches use CoD training and testing. Reactive agility training and assessment are more applicable to team sports since players practically never execute CoD 5-0-5 actions without stimulus. One of the main weaknesses of this study is that it does not have test-retest reliability. So, there is no familiarization testing that was performed. This is primarily a result to the emergence of COVID-19 pandemic which continues to ravage the country forcing people to practice social distancing and self and forced isolation. This is, of course, a major weakness in the study. Another weakness is that there is no directly eccentric horizontal movement, only vertical (eccentric phase of CMJ). This can for future researched be evaluated and compared to phase specific components of CoD.

Despite the positive findings of this research, many unanswered issues remain. The precise relationships between the many strength characteristics exhibited during CoD tasks, such as various movement phases (acceleration, braking, cutting, and re-acceleration) and force generation asymmetry (left and right; dominant and non-dominant). Additional research is required.

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APPENDICES ONE
LETTER OF CONSENT

Forespørsel om deltakelse i forskningsprosjektet

"Utvikling av testbatteri ved Olympiatoppen"

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke hvilke fysiske tester som skal inngå ved fysisk testing på Olympiatoppen. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

FORMÅL

Det er en tradisjon med testing av vertikale bevegelser for å beskrive fysiske egenskaper (kraft, hastighet og power) til idrettsutøvere i ballidrett (lag og individuell). Samtidig vet vi at sprint og retningsforandring er grunnleggende og viktige egenskaper innen ballidrett som stiller krav til de samme fysiske egenskapene horisontalt (spesifisitetsprinsippet). Olympiatoppen ønsker en gjennomgang og oppgradering av sine testbatteri hvor inkludering av horisontale tester kan være en slik utvikling. En del av prosjektet vil være å analysere historiske data (vertikal tester) mot prestasjon. Deretter inkludere nye horisontale tester (hopp og retningsforandring) for analysere sammenhengen mellom horisontale og vertikale tester samt sammenhengen mellom disse og prestasjon. Dette for å validere eventuelt behovet for inkludere horisontale tester i et nytt testbatteri.

Forsøkspersonene skal være friske kvinner og menn i alderen 16-40 år fra ulike ballidretter med erfaring fra styrketrening og eksplosiv testing av styrke. Prosjektet innebærer at du vil bli testet med 3 horisontale hopp på hvert bein og 505 tester med belastning.

HVA INNEBÆRER DELTAKELSE I STUDIEN?

Deltakere i denne studien skal gjennomføre et etablert testbatteri (hopp på kraftplatform, reach test, beinpress og sprint) samt to nye tester: 1) ettbeins sideveis hopp med motstand og 2) retningsforandring (505 test) med motstand. Den ytre motstanden som skal brukes for begge disse testene er fra robotikk, som betyr at den kommer fra en elektrisk motor. Denne motoren er koblet til en trommel som har en line som så festes til et belte som deltakeren har rundt hoften. Med denne motstanden skal utøveren så gjennomføre ettbeins sideveis hopp fra begge bein. Testen for retningsforandring inneholder en 5m akselerasjon med oppbremsing mot en retningsforandring (180 grader) med en påfølgende akselerasjon (5m). Det vil være tre repetisjoner per hopp per bein, og to repetisjoner per bein per retningsforandring.

Alle deltakere vil få en økt innsikt i evnen til skap kraft og hastighet horisontalt og vertikalt. Dette er nyttig informasjon for utøver og trener med tanke på egenskaper og vurderinger rundt eget treningsarbeid.

Videre ønsker vi å bruke historiske data fra fysiske tester ved Olympiatoppen. Analyser av tidligere testresultat vil bli gjort anonyme data som er anonymisert og din identitet vil ikke være kjent.

Mulige ulemper med deltakelsen i denne studien er at deltakerne selv må sette av tid til testing. Uansett, testingen vil gjennomføres samtidig med testene du gjør i idretten din. Gjennomføring av testene innebærer alltid en viss risiko for skader, men det er ingen grunn til at denne risikoen er høyere ved deltakelse i denne studien enn ved egen trening og deltakelse i ballidrett. Testingen kan medføre midlertidig muskeltretthet og stølhet, men dette er ikke skadelig.

HVA SKJER MED INFORMASJONEN OM DEG?

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket. Alle personopplysninger vil bli behandlet konfidensielt og uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger. Det betyr at resultatene blir ikke lagret under navnet, men med en kode. Navnet ditt blir derfor koblet til en kode som vil oppbevares i en safe ved NIH som kun to prosjektmedarbeidere har tilgang til. Etter prosjektslutt skal kodelisten slettes og dermed vil all data være anonymisert. Dine personopplysninger vil ikke kunne identifiseres i publikasjoner.

Prosjektet skal etter planen avsluttes 01.08.2022. Vi er pliktet til å oppbevare data og separat navneliste i 5 år etter sluttdato for etterprøvbarhet og kontroll av resultatene. Etter dette, altså 01.08.2027, vil all data i prosjektet slettes.

Prosjektleder har ansvar for den daglige driften av forskningsprosjektet og at opplysninger om deg blir behandlet på en sikker måte. Dine rettigheter: Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg
- få rettet personopplysninger om deg
- få slettet personopplysninger om deg
- få utlevert en kopi av dine personopplysninger (dataportabilitet), og
- å sende klage til personvernombudet eller Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler opplysninger om deg basert på ditt samtykke.

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

FRIVILLIG DELTAKELSE

Der er frivillig å delta i prosjektet Hvis du velger å delta, undertegner du samtykkeerklæringen på siste side. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke. Dersom du trekker deg fra prosjektet, kan du kreve å få slettet innsamlede prøver og opplysninger, med mindre opplysningene allerede er inngått i analyser eller brukt i vitenskapelige publikasjoner. Alle opplysninger om deg vil da bli anonymisert. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg. Dersom du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med prosjektleder Ola Eriksrud (ola.eriksrud@nih.no/97617893), vårt personvernombud

(personvernombud@nih.no), eller NSD – norsk senter for forskningsdata (personverntjenester@nsd.no / 55582117).

FORSIKRING

Alle deltakerne er forsikret ved at NIH som statlig institusjon er selvassurandør.

GODKJENNING

Studien er godkjent av intern etisk komite ved Norges idrettshøgskole (saksnummer).

SAMTYKKEERKLARING

Jeg har mottatt og forstått informasjon om prosjektet *Reliabilitet av retningsforandringstester ved bruk av robotisk motstand*, og har fått anledning til å stille spørsmål.

Jeg samtykker til:

- ☐ å delta i prosjektet som er beskrevet ovenfor
- ☐ at mine opplysninger behandles frem til prosjektet er avsluttet (01.08.2022) og lagres i 5 år etter prosjektslutt.

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Sted og dato Deltakers eller foresattes signatur

Deltakers eller foresattes navn med trykte bokstaver

APPENDICES TWO

Reliability of change of direction testing using robotic resistance technology

Frederic Westheim[1], Håkon Laugsand[1], Paul Solberg[2], Ola Eriksrud[1]

[1]Department of Physical Performance, Norwegian School of Sport Sciences, Oslo, Norway

[2] Norwegian Olympic and Paralympic Committee and Confederation of Sport, Oslo, Norway

INTRODUCTION:

Current change of direction (CoD) tests (multiple phases with one or more turns) have been critized as they do not quantify phase specific information from the initial acceleration to deceleration and re-acceleration phases (Nimphius, Callaghan, Bezodis, & Lockie, 2017). Reliable and accurate phase specific outcome measurements can provide important information to athletes as acceleration and deceleration represent different physical qualities, which subsequently can be used in the individualized training prescription. The purpose of this study was to determine test-retest reliability of overall and phase specific performance measurements of the modified 505 (m505) test using a robotic resistance device.

METHODS:

Seven male (age 24±5 years; height 181±3 cm; body weight 81±5 kg) and three female (age 21±1 years; height 176±9 cm; body weight 71±4 kg) ball game/team sport athletes completed two familiarization and two test sessions. After a standardized warm-up each athlete performed two m505 turning off the left (L) and right (R) foot with a 3 kg external load using a robotic resistance device (333 Hz) (1080 Sprint, 1080 Motion AB, Lidingø, Sweden). Specifically, the athlete performed the initial acceleration to deceleration (phase 1a) running toward, while the re-acceleration (phase 1b) running away from the robotic resistance device. The CoD is defined as the time when velocity change direction in the robotic resistance device. The outcome measurements provided by the system and analyzed in the current study are overall time and phase specific (1a and 1b) time and average velocity. Test-retest reliability was calculated from test session one and two using correlational analysis (r), intraclass correlation coefficient (ICC), typical error (TE), coefficient of variation (CV) and interpreted based on established guidelines (2).

RESULTS:

Overall time (L: 3.05±.14; R: 3.06±.23) had good to excellent correlations (L: .77; R: .93), good ICC values (L: 0.82; R: 0.80), good CV (L: 2.3 ; R: 3.8) and TE values (L: .07; R: .08) Phase 1a time (L: 1.70±.09; R: 1.69±.12) and average velocity (L: 2.83±.17; R: 2.87±.19) had good to excellent correlations (range: .71 to .88), good ICC values (range: 0.76 to 0.90), good CV (range: 1.1 to 3.0) and TE values (L and R time .05 sec; L and R average velocity: .07 m/s). Phase 1b time (L: 1.34±.07; R: 1.35±.09) and average velocity (L: 3.60±.20; R: 3.57±.19) had good to excellent correlations (range: .79 to .96), good ICC values (range: 0.76 to 0.97), good CV (range: 2.5 to 3.1) and TE values (L time .03 sec; R time: .04 sec; L average velocity: .07 m/s; R average velocity: .04 m/s).

CONCLUSION:

Overall and phase specific outcome variables obtained by a robotic resistance device from the m505 test have good to excellent test-retest reliability.

REFERENCES: Nimphius et al., J Strength.Cond.Res, 2017. Hopkins., Sportscience, 2015

APPENDICES THREE

Soft wear set up using 1080 sprint

Purpose: generate power, force and time variables at different movements

Equipment: 1080 Sprint and belt

Position 1080 Sprint: Secure 1080 Sprint on top of a table at 100 centimeters height (apprimately hip hights)

Preparation: Make sure equipment is connected to power source and that the emergency button is greenn, signaling power supply. Set up tablet and connect. Start the application (1080 motion) and log on. Select or create client to be tested > create new session > add exercise (505 and lateral jump) (Figure 1) > view exercise.

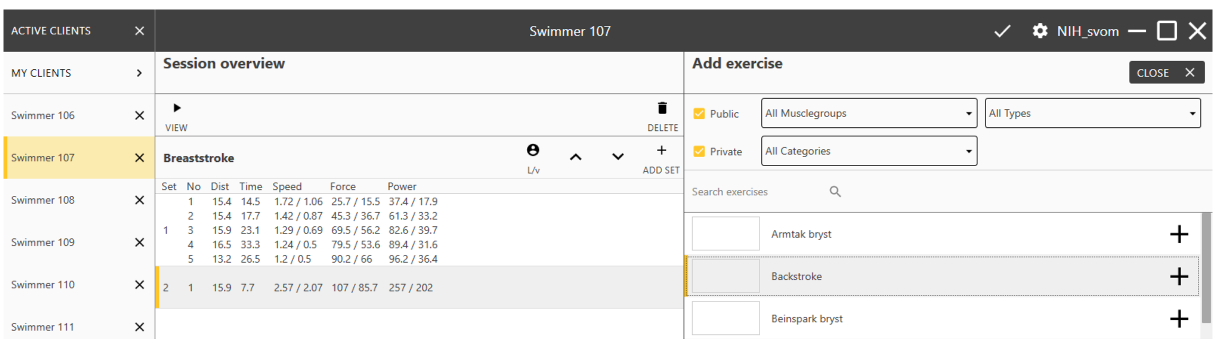

Figure 1.

Calibration: set load to 0 kg and pull line out to 5 m away from the Sprint. Then hit the set position button (Figure 2)

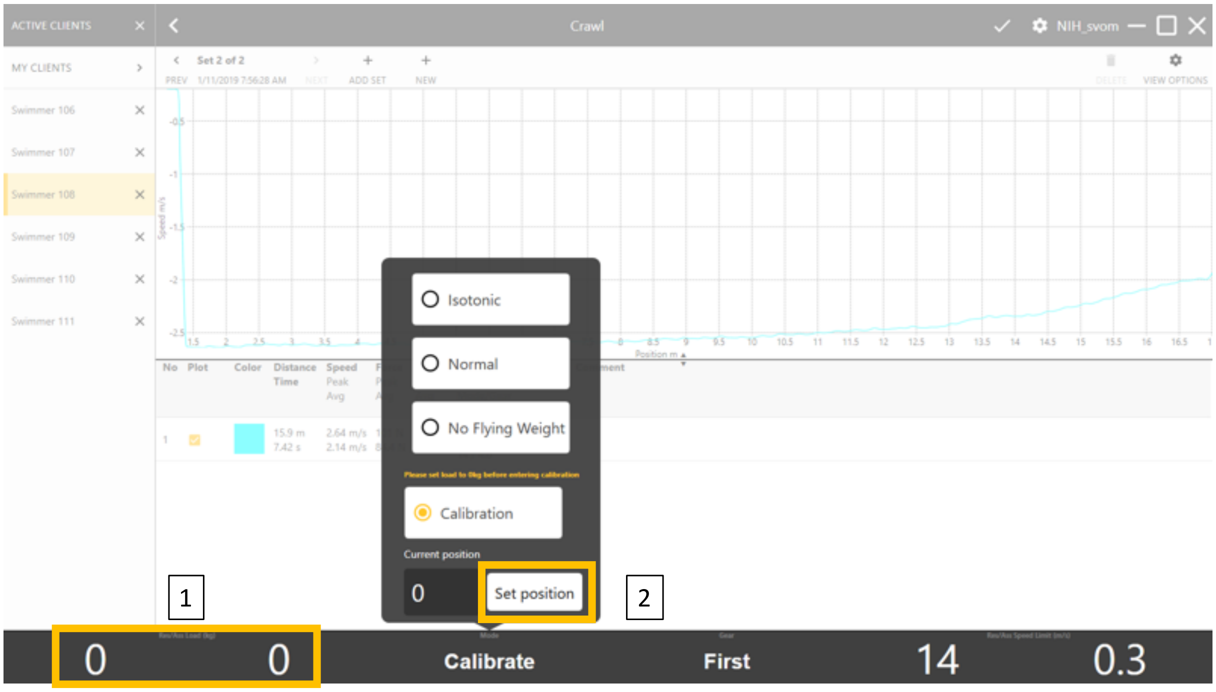

Figure 2.

Settings:

- Mode: The default when starting the system is isotonic. Figure 3 shows how to change the default. No flying weight was used for both test protocols

Figure 3.

Figure 4 shows gearing First gear is set to default when login in. For both protocols first gear was used

Figure 4.

- Figure 5 shows Concentric load, which was set at 3 kg
- Figure 7 also shows Eccentric load, which was also set at 3 kg

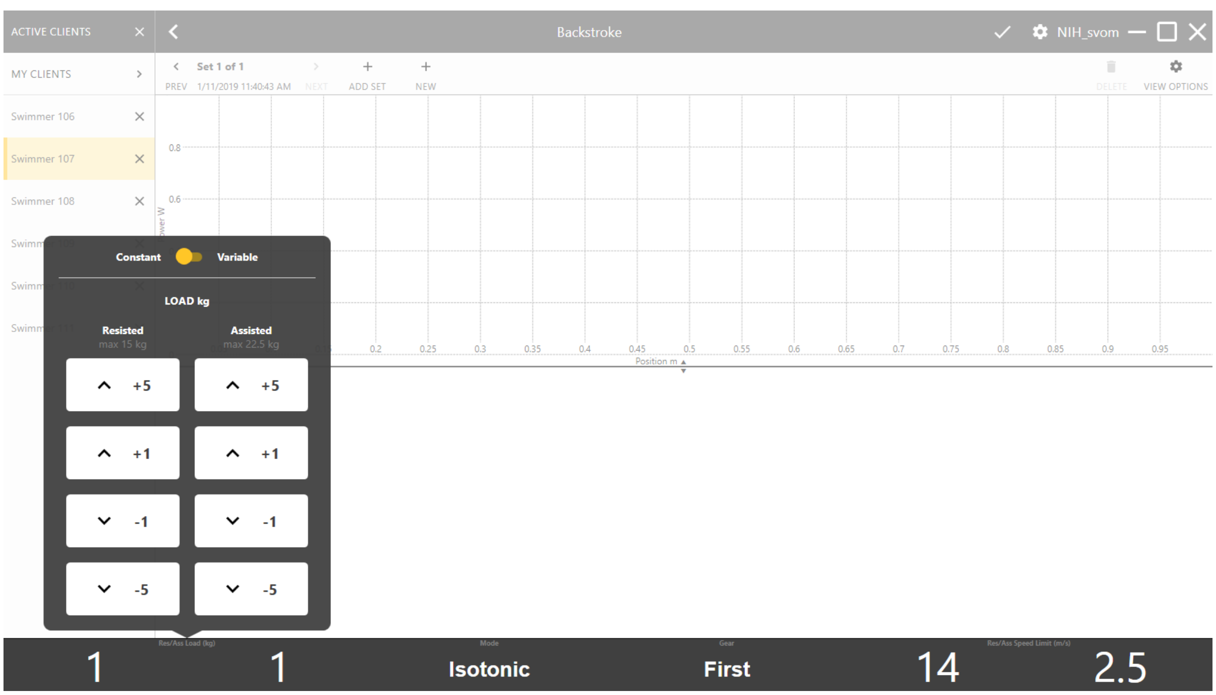

Figure 5.

- Assisted/concentric speed: 14 m/s for 505 and 6 m/s for lateral jump
- Resisted/eccentric speed: 14 m/s for 505 and lateral jump

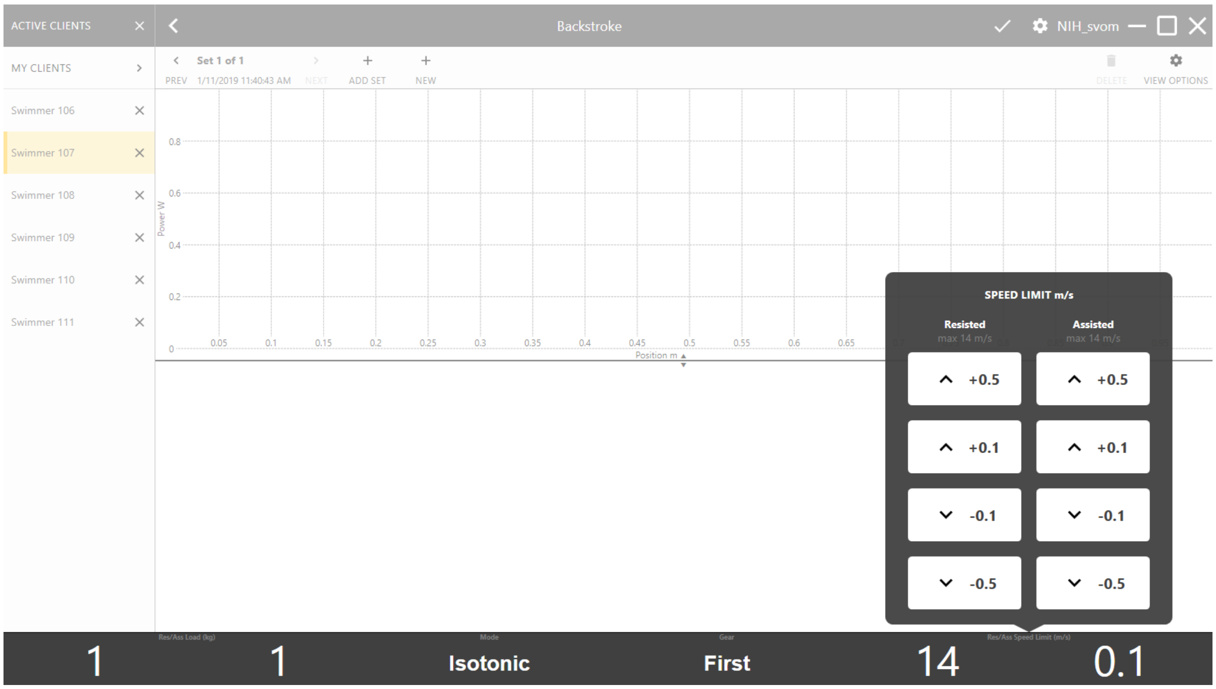

Figure 6.

Recording:

- Select protocol (505 and laterla jump used)

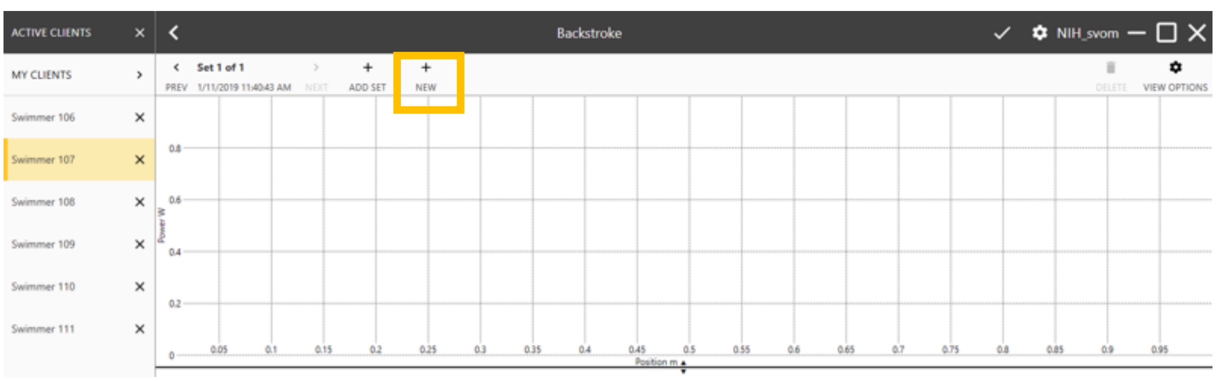

Figure 7.