Individualized Power Training Based on the Theoretical Force-Velocity Profile: Efficient or too many pitfalls?

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TABLE OF CONTENT

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Sammendrag

Hensikt: Målet med denne studien var å utforske om et individualisert power-treningsprogram som er basert på den teoretiske individuelle kraft-hastighetsprofilen (KH) er mer effektiv enn et balansert power-treningsprogram for å forbedre sprint- og hopprestasjon. **Metode:** Førti nasjonale eliteutøvere fra håndball og fotball (alder 22 ± 4, høyde 183 ± 10 og kroppsmasse 84 ± 15) gjennomførte en 10-ukers treningsintervensjon. Utøvernes teoretiske optimale kraft-hastighetsprofilen ble utviklet med knebøyhopp med forskjellig belastning (0,20,40,60.80 kilogram), og basert på utøvernes KH-profil så ble de kategorisert som enten kraft- eller hastighetsdominante. Gjennom randomisering ble utøverne plassert til å trene mot eller uavhengig av sin teoretiske optimale kraft-hastighetsprofil, og fikk tildelt treningsprogram deretter. **Resultat:** Både før og etter intervensjonen gjennomførte utøverne 20-meter sprint, knebøyhopp, hopp med motbevegelse (CMJ) og en pneumatisk Keiser power benpress. Ingen signifikante endringer i 20 meter sprint (-0.7% og -0.60%), CMJ (0.9% og 2.4%), maksimal powerutvikling (P_{max}) (-0.1% og -1.6%), maksimal kraftutvikling (F_0) (-0.4% og -1.9%), maksimal hastighetsutvikling (V_0) (0.0% og -0.7%) og den teoretiske optimale KH-profilen (-0.4% og 4.2%) ble observert i både den individuelle og balanserte treningsgruppen, henholdsvis. Studien fant ingen signifikante gruppeforskjeller i de målte variablene. **Konklusjon:** Funnene fra denne studien støtter ikke at et individualisert treningsprogram basert på den teoretisk individuelle KH-profilen er mer effektivt for å forbedre sprint- og hoppferdigheter enn et balansert treningsprogram.

Nøkkelord: Styrketrening, håndball, fotball, kraft-hastighetsprofil, løping, spenst, eksplosiv styrke

Abstract

Purpose: The present study aimed to examine if an individualized power training program based on the theoretical individual force-velocity (FV) - profile is superior to a balanced power training program to enhance jumping and sprinting performance. **Method:** Forty national elite level athletes (age 22 ± 4, height 183 ± 10, and body mass 84 ± 15) from handball and football completed a 10-week training intervention. A theoretical optimal individual squat jump FV profile was created from SJ with various loads (0,20,40,60.80 kilograms), and based on their actual FV-profile they were categorized as either force or velocity dominant. The athletes were randomized to train toward (individualized) or irrespective (balanced) of their theoretical optimal FV-profile, and they were assigned training programs accordingly. **Results:** The athletes performed a 20-meter sprint, SJ, countermovement jump (CMJ) and a Keiser leg-press power test before and after the training intervention. No significant changes in 20-meter sprint (-0.7% and -0.60%), CMJ (0.9% and 2.4%), maximal power output (P_{max}) (-0.1% and -1.6%), theoretical maximal force output (F_0) (-0.4% and -1.9%), theoretical maximal velocity output (V_0) (0.0% and -0.7%) and the theoretical FV-profile (-0.4% and 4.2%) were observed in either the individualized or balanced training group, respectively. No significant between-group differences were observed. **Conclusion:** The findings from this study did not support that an individualized power training program based on SJ-FV-profiling is superior to a balanced power training program.

Keywords: Resistance training, handball, soccer, force-velocity profile, running, jumping, explosive strength

Abbreviations

FV	Force-Velocity
FV_{imb}	Force-Velocity Imbalance
P_{max}	Maximal Power Output
CMJ	Counter Movement Jump
RFD	Rate of Force Development
CSA	Cross-Sectional Area
SSC	Stretch-Shortening Cycle
V_{max}	Maximal Velocity Shortening
ATP	Adenosine 5'-triphosphate
F_0	Theoretical Maximal Force
V_0	Theoretical Maximal Velocity
SD	Standard Deviation
Cm	Centimeter
Kg	Kilogram
RIR	Repetitions in Reserve
1RM	One-Repetition Maximum
S	Seconds
Min	Minutes
N	Newton
M/s	Meters per second
W	Watt
RCT	Randomized Controlled Trial
CV	Coefficient of Variation

Structure of the thesis

Part 1: Presents the theoretical background for the study, a methodological chapter of how the study was performed, and a chapter discussing the methodology.

Part 2: Presents a research paper, written following the guidelines from the open access of the Scandinavian Journal of Medicine & Science in Sports. Part 2 consists of an AMA-style manuscript: Introduction, methods, results, discussion, strengths, and limitations of the study, and perspectives.

Part 3: Consists of appendices such as approval, informed consent, and application of ethical approval.

PART 1

THEORETICAL BACKGROUND

AND METHODS

TABLE OF CONTENT

1.0 Introduction

Handball and European football are Olympic sports that are played worldwide and at a highly professional level in many countries, and performance depends upon a variety of individual skills and interaction with their teammates (Haugen et al., 2014; Póvoas et al., 2012). The technical and tactical skills of each player are important determinants of performance, but the development of physical capabilities is essential to perform at the highest level (Faude et al., 2012; Gorostiaga et al., 2005; Haugen et al., 2014; Póvoas et al., 2012). Handball and football consist of high-intensity actions like sprinting, jumping, and changes of directions, and it is suggested that powerful players that are great at sprinting and jumping have better chances of success (Faude et al., 2012; Gorostiaga et al., 2005; Haugen et al., 2014; Póvoas et al., 2012). Because individuals respond differently to exercise training and it exists a large individual variation, the need for an efficient individualized training method is immense (Wilmore et al., 2015). Thus, the method of individualizing training based on the force-velocity (FV) profile was formed, and it is based on the concept of a theoretical optimal FV profile (Samozino et al., 2011).

Samozino et al. (2011) suggest that the optimal FV profile consists of an ideal balance between force and velocity-producing capabilities, which maximizes performance in explosive movements such as jumping and sprinting. Muscular power is a strong predictor of performance in explosive movements, and it is theorized that an athlete that produces his theoretical maximal power (P_{max}) at a load greater than bodyweight is categorized as force dominant, whereas producing the theoretical P_{max} at a load lighter than bodyweight makes the athlete velocity dominant (Samozino et al., 2011; Sleivert & Taingahue, 2004). The distance between the optimal profile and the actual measured FV profile is termed FV imbalance (FV_{imb}) (Samozino et al., 2011). Both theoretically and experimentally the FV_{imb} have been associated with jumping performance, which means that one can predict an athlete's jumping performance through their FV_{imb} and P_{max} (Álvarez et al., 2020; Jiménez-Reyes et al., 2017; Samozino et al., 2011; Simpson et al., 2021).

In practice, the athlete targets its least developed capacity (force or velocity), and if an athlete is force dominant, the training program should consist of high-velocity exercises, whereas an athlete that is velocity dominant, should do more high-force exercises (Samozino et al., 2011). Initial results were promising; however, recent research has shown conflicting results, and some questions remain unanswered (Álvarez et al., 2020; Jiménez-Reyes et al., 2017; Lindberg et al., 2021c; Rakovic et al., 2018; Simpson et al., 2021). The studies that support this method found improvements in jumping performance only, which is not the only important performance determinant in sports like handball and football (Álvarez et al., 2020; Jiménez-Reyes et al., 2017; Simpson et al., 2021).). It is uncertain if reducing FV_{imb} without changing P_{max} will improve other performance measures like 20 m sprint, countermovement jump (CMJ), and measures of power in the Pneumatic Keiser Leg Press. In addition, it is uncertain if an athlete should focus on their weak ability when it potentially could be a sign of greater response to a specific stimulus (Mangine et al., 2018).

1.1 Purpose

Due to the conflicting results regarding FV-profiling, the purpose of this present study was to investigate if an individualized power training aimed at reducing the FV_{imb} is superior to a balanced power training for improvements in jumping and sprinting performance, and other performance measures such as maximal power, force, and velocity output in elite national athletes.

2.0 Theoretical framework

2.1 Which physical characteristics are important for optimal performance in power demanding sports?

In many sports movements like sprinting, jumping, changes of direction, throwing, or kicking, you must perform a large amount of work per unit of time and the demands of producing a high amount of force at high velocities are huge (Cormie et al., 2011b; Young, 2006). This is often referred to as power, which is defined as the rate at which work is performed and is the product of force and velocity. P_{max} is the explosive component of strength and consists of both the strength and velocity aspects of a movement (Wilmore et al., 2015).

In football and handball, there are several high-intensity actions such as stops, changes of directions, sprinting, jumping, sideway high-intensity movements, and one-on-one situations during a game (Póvoas et al., 2012). Another study that looked at the differences between elite and amateur handball players suggested that muscular and powerful players have greater chances to succeed in the sport (Gorostiaga et al., 2005). Further, it seems like the amount of high-intensity activities differentiates top-class players from those of a lower calibre in football (Mohr et al., 2003).

2.2 The importance of sprinting and jumping ability in handball and football

Time-motion analyses have demonstrated that short sprints occur frequently during football games and that professional players are greater at sprinting compared to the inferior ones (Haugen et al., 2014). A study from the first German national league observed that 83% of the goals were preceded by at least one powerful action by the scoring or the assisting player, where straight sprints (45%) and jumps (16%) were most typical (Faude et al., 2012). During the transition phase in handball, the defenders and attackers sprint to prevent or score a goal, goals are often preceded by a jump (Póvoas et al., 2012). It has been observed a negative correlation between maximal power during squats and split squats with 5-meter (m) sprint time (r= -0.64 to r= -0.68) (Sleivert & Taingahue, 2004). Elite handball players have shown 16-22% greater values in absolute maximal strength and P_{max} in the bench press, and P_{max} in the half squat compared to amateur players (Gorostiaga et al., 2005). Success in power-demanding sports can therefore be determined by the ability to make repeated explosive muscular contractions (Bragazzi et al., 2020). A Meta-Analysis showed that resistance training significantly improved both isometric strength, maximal strength power, and throwing ability in handball players, which emphasizes the importance of an optimal training program (Bragazzi et al., 2020).

2.3 What determines sprinting performance?

To describe sprinting the gait cycle is often used, which consists of four phases: The braking, mid-stance, late stance phase, and ends at the toe-off (Howard et al., 2018). The relevant muscles which determine sprint performance contribute at different rates, depending on which phase you are in (Howard et al., 2018).

Applying great forces to the ground to reach faster top speeds is essential, whereas faster sprinters have demonstrated significantly greater force application, shorter ground contact time, and covered a larger distance per stride compared to slower sprinters (Weyand et al., 2000). Applying high amounts of force in the horizontal direction is closely related to 100-m sprinting performance and P_{max}, which is affected by the lower limb strength and the ability to transfer it to specific forward sprint motion (Morin & Samozino, 2016). It has been detected a great relationship between short-distance sprint performance and horizontal force production, which is directly related to handball and football athletes where the ability to accelerate and sprint over shorter distances is essential (Faude et al., 2012; Gorostiaga et al., 2005; Haugen et al., 2014; Morin & Samozino, 2016; Póvoas et al., 2012). Sprinting and jumping are characterized by short ground contact times, which are often performed within 30-200 milliseconds (Taber et al., 2016). A greater force applied creates a greater impulse, momentum, and a higher power output, which makes it optimal to produce the force quickly (Taber et al., 2016). This is often referred to as the rate of force development (RFD) and describes the degree of force that can be produced at a minimal time, which is often used as an index for explosive strength (McLellan et al., 2011).

2.4 What determines jumping performance?

Jumping can be defined as the ability to accelerate body mass, as much as possible within the shortest possible time, and is determined by a complex interaction among several factors, which includes maximal force by the lower limbs, RFD, and neuromuscular coordination (McLellan et al., 2011; Samozino et al., 2011). Jumping is reliant on the velocity at take-off, which is affected by the net mechanical impulse produced into the ground (Winter, 2005). The net machinal impulse is calculated as the force produced multiplied by the time over which that force is exerted, and the ability to produce a high net impulse has been associated with muscular mechanical power output capabilities (Newton & Kraemer, 1994; Winter, 2005). Increasing squat depth has been observed to enhance the net vertical impulse and jumping performance for both static jump and CMJ (Kirby et al., 2011). The static jumps were performed at multiple different heights, and the relative net impulse (net vertical impulse divided by body mass) showed a statistically significant correlation to jump height across all depths. A larger range of motion allows the muscles to exert force for a longer duration of time before take-off, which increases the relative ned impulse, and can therefore be used to indicate vertical jumping performance (Kirby et al., 2011). This can be used especially in sports like volleyball, but also in football before a head duel.

2.5 Neuromuscular factors that determine power, sprinting, and jumping performance

2.5.1 Morphological factors

Muscle size

The total surface of a muscle when it is viewed perpendicular to the direction of the muscle fibers is referred to as muscle cross-sectional area (CSA), and generally, a long-term improvement in force production is a result of an increased CSA (Lexell & Downham, 1992; Wilmore et al., 2015). There is a directly proportional relationship between a single muscle fiber CSA and the capability of force generation (Widrick et al., 2002). Since maximal force output influences $P_{max,}$ an increase in CSA through muscle hypertrophy can be advantageous for improving performance (Widrick et al., 2002). Increased muscle size is generally related to increased force production, and it is therefore tempting to conclude that a direct cause-and-effect relationship exists between these two, but there are multiple other factors to take into account (Wilmore et al., 2015).

The CSA of the gluteus maximus ($r = -0.366$, $p<0.05$) and psoas major ($r = -0.388$, $p <0.05$) have shown high correlations with 100-m sprint performance, and were 18.4% and 21.7%, respectively, larger in sprinters than in non-sprinters (Tottori et al., 2021). Peak activity for the gluteus maximus was found at foot-strike, with activity in the early stance phase, but showed also activity in the late swing phase, where it contributes to decelerating the forward swing of the leg (Howard et al., 2018; Tottori et al., 2021). The contribution of the gluteus maximum also increases the step rate as the velocity increases, where psoas major does hip flexion and contributes to rapidly accelerating the leg forward during the swing phase (Tottori et al., 2021). It happens a stretch-shortening cycle (SSC) for the hamstring during sprinting, which is characterized by an eccentric phase followed by an isometric transitional period (amortization phase), which leads to an explosive concentric action (Turner et al., 2010). The hamstrings eccentric phase occurs during the swing phase where it produces peak forces, and the shortening happens just before the foot strike and continues throughout the stance (Schache et al., 2012). It should be mentioned that it has been observed no relationship between CSA of the hamstrings and sprint performance (Tottori et al., 2021).

Muscle Fiber Type

Power production is largely determined by the muscle fiber type distribution, and strength and power athletes have shown to have a large share of fast-twitch muscle fibers, which has shown to generate more power per unit of CSA (Bompa & Haff, 2009; Tihanyi et al., 1982). Differences in specific force (maximal force production/CSA), maximum shortening velocity (V_{max}), and the curvature of the FV curve amongst the fibers types affect peak power per unit CSA (Widrick et al., 2002). The V_{max} is theorized to have the biggest impact on the difference in P_{max} between the muscle fibers types due to a more rapid cross-bridge cycle (Lieber, 2011). The type II fiber can reach peak tension (50ms) quicker compared to type I fiber (100ms) and generate three to five times greater power than type I, which is a result of a faster form of myosin ATPase (adenosine 5'-triphosphate) and a more developed sarcoplasmic reticulum (Wilmore et al., 2015).

It has been observed a correlation between SJ height and lean body mass of the lower extremities and CSA of type IIX fibers (r= 0.32 and 0.32 $p \leq 0.05$, respectively), and CMJ and the fascicle length of the vastus lateralis (r= 0.32, $p \leq 0.05$) (Methenitis et al., 2016). A champion sprint runner showed a relatively high proportion of type IIA fibers and an extraordinary amount of type IIX fibers (Trappe et al., 2015). Thus, jumping performance requires lower or moderate extremities lean body mass, a high percentage of fast-twitch fibers, and long fascicle lengths (Methenitis et al., 2016; Trappe et al., 2015).

It has been observed that both heavy strength and sprint training have decreased the amount of type I fibers and promoted a fiber shift from type IIX to type IIA (Adams et al., 1993; Andersen et al., 1994). Therefore, the loss of type IIX fibers could potentially happen before sprinters are introduced to strength training (Andersen et al., 1994). The increase in CSA in type IIA fibers outweighs the loss of type IIx fibers (Jansson et al., 1990). Liu et al (2003) found that a combination of both heavy and explosive strength training increased type IIA fibers, reduced the loss of type IIX fibers, and decreased type I fibers (Liu et al., 2003). A training period of 20 weeks with heavy resistance training showed a hypertrophic response in all fiber types, but a larger increase in fast-twitch fibers, which resulted in an increased type II to type I fiber ratio (Staron et al., 1990). Since a high proportion of type II fibers has been linked to both jumping and sprinting performance, this increased ratio would lead to enhanced performance (Methenitis et al., 2016; Trappe et al., 2015). However, a large amount of endurance training can promote a shift from fast-twitch to slow-twitch fibers and must be considered when programming for athletes (Luden et al., 2012).

Length-Tension Relationship

Each muscle fiber has an optimal sarcomere length where it exists a preferred overlap between actin and myosin filaments, and the cross-bridging is maximized and allows the greatest force development (Wilmore et al., 2015). Force production is therefore reduced when the sarcomere is shortened or stretched below or beyond the optimal length (Gordon et al., 1966). An efficient cross-bridging during the short ground contacts is vital for maximizing sprinting and jumping performance (McLellan et al., 2011; Weyand et al., 2000; Wilmore et al., 2015). The short ground contacts are characterized by SSC actions, where the fast eccentric phase allows muscles to build up a high level of active state and force before the shortening phase, which will lead to greater force production over the first part of the shortening distance (Bobbert et al., 1996). Drop jump with short ground contact time and CMJ are observed to correlate significantly negatively with 30-m sprint performance (r= -0.79 and -0.60, respectively), which emphasizes the need for an efficient SSC (Hennesy & Kilty, 2001).

When an active muscle-tendon unit is stretched, the mechanical work is absorbed and potentially stored as elastic energy in the series of elastic components, which includes fiber cross-bridges, aponeurosis, and tendon (Cavagna et al., 1968; Kubo et al., 1999). The elastic elements act as an energy supplier to maximize power output (Cormie et al., 2011a). During jumping and sprinting our leg spring compresses on ground contact and stores energy, before rebounding at push-off and releasing energy (Hobara et al., 2008). The released energy makes the muscle fibers work closer to their optimal length due to minimal displacement and enhances force production (Kawakami et al., 2002). The muscle-tendon unit works at high shortening velocities, but the change of the fascicle length happens at a slower speed which leads to a greater force production potential, according to the FV relationship (Fukashiro et al., 2006). A tendon with high stiffness can potentially release more elastic energy quicker (Turner et al., 2010). Power athletes have demonstrated significantly higher leg stiffness in the knee, ankle, and hip joints compared to endurance athletes (Hobara et al., 2008). An investigation of jumping athletes found that the preferred jumping leg showed greater stiffness in the Achilles tendon and therefore produced more force compared to the nonpreferred leg (Bayliss et al., 2016). Additionally, the force production of the Achilles Tendon increases as the sprinting velocity increases (up to 6 m/sec), which emphasizes the role of tendon stiffness (Mero et al., 1992). A combination of heavy and explosive strength training has been observed to increase the knees tendon stiffness to a greater extent compared to heavy or plyometric training alone (Toumi et al., 2004).

Pre activation or potentiation of the cross-bridges is believed to enhance force production of the contractile elements in the shortening phase (Cavagna et al., 1985). A strained cross-bridge is more efficient to re-attach and contract and makes the cross-bridging more efficient (Cavagna et al., 1985). During the eccentric phase, it happens a lengthening of the muscle-tendon unit that deforms the muscle spindles, and triggers the sensory neurons to send action potentials to the spinal cord (Wilmore et al., 2015). This leads to an activation of the alpha-motor neurons' stretch reflexes to overcome the stretch and increase the force production in the upcoming concentric phase (Gollhofer & Komi, 2014; Wilmore et al., 2015).

Muscle architecture

Skeletal muscle architecture is defined as the arrangement of muscle fibers within a muscle relative to the axis of force generation (Lieber & Fridén, 2001). The physiological CSA and fiber length affect force development (Kruse et al., 2021). Compared to CSA the physiological CSA takes fiber angle into account, which is largely determined by pennation angle, which describes the angle of muscle fibers with respect to the line of pull of the muscle (Kruse et al., 2021). The force exerted actively by the muscle can be expressed as a function of muscle length, where the optimum length is referred to as the muscle length where the muscle produces maximal active force, and the active slack length is referred to as the muscle length where the muscle does not generate force actively (Kruse et al., 2021).

Muscle fibers contain sarcomeres, and the force-generating ability of these is determined by the number of sarcomeres that are arranged in parallel and series (Gans, 1982). An increased pennation angle can lead to more sarcomeres in parallel, and therefore increase the force production since more contractile tissue can attach to a given area of a tendon and it allows the muscle fiber to shorten less for a given tendon displacement and operate closer to the optimum length (Gans, 1982; Muhl, 1982). Greater pennation angles are related to slower contraction velocities, and therefore decrease the muscle fiber's ability to shorten rapidly, which can inhibit power production (Spector et al., 1980).

The number of sarcomeres in series is strongly correlated to a muscle's V_{max} (Kruse et al., 2021). Arranging sarcomeres in series will increase fascicle and muscle fiber length, and the V_{max} of a muscle fiber is proportional to its length, given a constant level of activation (Wickiewicz et al., 1983). Superior sprinters have shown greater fascicle length in both vastus lateralis and gastrocnemius compared to long-distance runners and untrained subjects, and the fascicle lengths of these are significantly related to 100-m sprint performance (r= -0.43 and -0.57, respectively) (Abe et al., 2001; Kumagai et al., 2000). If this is a result of training adaptation or a genetic predisposition is uncertain (Abe et al., 2000). Adding sarcomeres in series is also related to a reduced pennation angle and an increased muscle length range of active force exertion (distance between the optimum and active slack length), which will inhibit force production (Kruse et al., 2021).

Bodybuilders have shown to have larger pennation angles than untrained subjects, and highly trained sprinters have shown to have smaller pennation angles than less trained sprinters (Kawakami et al., 1993; Kumagai et al., 2000). This can indicate that heavy strength training increases the pennation angle and sprinting and jumping decreases it, which also has been demonstrated in some studies (Aagaard et al., 2001; Blazevich et al., 2003). Eccentric training has also proved to arrange sarcomeres in series, and therefore this type of training can be used to enhance sprinting and jumping performance (Morgan & Talbot, 2002).

2.5.2 Neural factors

Motor Unit Recruitment and Synchronization

The number and type of motor unit recruited is deciding how much force a muscle can produce, and according to the Henneman's size principle the smaller motor units are recruited before the large ones during voluntary contractions of increasing force (Henneman et al., 1974) The small α-motoneurons activate slow-twitch fibers at low force levels, and the large α-motoneurons activate fast-twitch fibers at higher levels of force (Henneman et al., 1974).
If the motor units can be activated and act more synchronously it may increase maximal force production and RFD (Wilmore et al., 2015). It is suggested that there is no evidence of selective recruitment of fast-twitch motor units in rapid concentric contractions (Desmedt &

Godaux, 1977). However, it is suggested that sprinters may have a greater ability to selectively recruit fast-twitch motor units compared to endurance and untrained individuals (Saplinskas et al., 1980). It is speculated that the motor units can exert their tension without having to overcome the elastic damping from the tendon, and therefore increase force production (Lind & Petrofsky, 1978). Therefore, it seems like this synchronization of motor units is a strategy of inter-muscular coordination and can impact both force and RFD during complex multi-joint movements such as jumping and sprinting (Mellor & Hodges, 2005).

Firing frequency

Firing frequency represents the degree of neural impulses which are transmitted from the α-motoneuron to the muscle fibers, and is important for force production (Cormie et al., 2011a). Increasing firing frequency is thought to be a result of an increase in the number of doublets, and was observed after a training period of 12-weeks with explosive resistance training, where the number of motor units who fired with doublets increased from 5% to almost 33% (Van Cutsem et al., 1998). This will result in improved fast-twitch fiber activation and increased force production at both fast and slow velocities, which contributes to increased maximal voluntary contraction speed and power output, and therefore enhances sprinting and jumping (Van Cutsem et al., 1998).

Inter-Muscular Coordination

Inter-muscular coordination is important when we are talking about the transfer to sports skills, and it is defined as the coordination and interactions of the muscles involved in a movement. Therefore, inter-muscular coordination reinforces the importance of movement-pattern specificity in a training program (Young, 2006). For a movement to be efficient it needs high activation of the agonist, increased activity by the synergists, and a decreased antagonist co-contraction (Cormie et al., 2011a). An increased coactivation of the antagonist would produce force in the opposite direction of the desired movement and weaken the full activation of the agonist through reciprocal inhibition, which potentially can have a negative transfer to athletic movements (Young, 2006). However, some coactivation is important to stabilize joints and coordinate movements (Cormie et al., 2011a). Thus, it is advantageous to decrease the coactivation of the antagonist to some degree (Young, 2006).

Sprinting and jumping are both categorized by triple extensions of ankles, knees, and hips, which demand suitable interactions between the musculotendinous units (Cormie et al., 2011a). Elite athletes have been observed to possess more developed motor programmes than inferior athletes, and also respond better to supra-maximal running as it increased both their stride rate and length (Mero & Komi, 1985). This indicates that well-trained athletes have greater neural adaptions to high-intensity sprint training compared to less-trained athletes (Mero & Komi, 1985). Alkjaer et al. (2013). suggested that 4 weeks of intensive drop jump training improved jumping performance due to an optimization of the coordination and activation pattern since there were lacking changes in isometric and isokinetic muscle strength and RFD. Ballistic, plyometric and weight lifting exercises can potentially increase both the rate of neural activation and inter-muscular coordination (Cormie et al., 2011b).

2.5.3 Muscle factors

Muscular FV Relationship

The FV relationship represents a characteristic property of muscle that determines power production capabilities and includes molecular and single-cell levels, whole muscle, and multi-muscle movements (Cormie et al., 2011a). To describe the inverse relationship between force and velocity during concentric muscle contraction the hyperbola (Figure 1) is often used, which suggests that a muscle can regulate the energy output depending on the load imposed on it (Hill, 1938). The sliding filament mechanism describes how the FV relationship is largely determined by the cyclic interaction between myosin heads in myosin filaments and the corresponding myosin-binding sites in actin filaments, which is coupled with ATP hydrolysis (Huxley, 1957). This interaction results in a conformational change in the cross-bridge, which causes the myosin head to tilt (power stroke) and drag the actin filaments toward the center of the sarcomere, which will shorten the sarcomere and generate force (Wilmore et al., 2015).

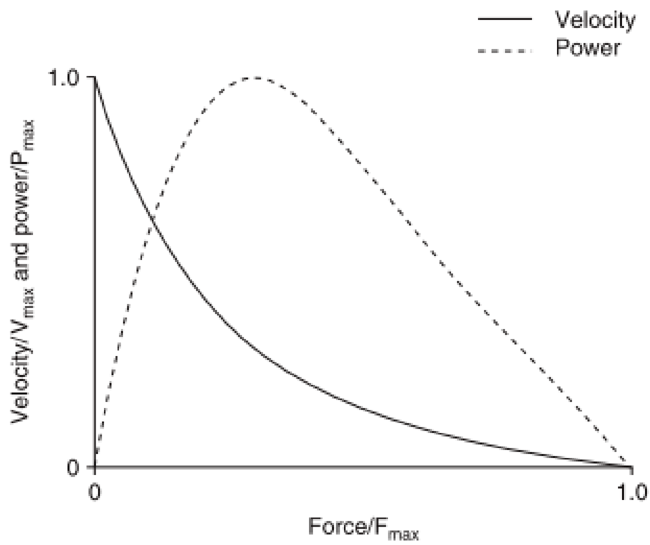

FIGURE 1 The FV and force-power relationship during concentric muscle contractions (Cormie et al., 2011a)

The current evidence suggests that the FV relationship in skeletal muscle follows a double-hyperbolic pattern, with a breakpoint located at very high forces and low velocities, which may be a result of the kinetic properties of myofilament cross-bridge formation (Alcazar et al., 2019). It also consists of deviations at low forces and high velocities, but this may be related to the calcium-independent regulatory mechanism of muscle contraction (Alcazar et al., 2019).

The FV relationship determines the pattern of the power-velocity relationship, and because of the non-linear FV relationship, the power-velocity relationship is slightly skewed towards lower velocities and higher force values (Jaric, 2015). Both the optimum external load and optimum shortening velocity are somewhat below 50% of their theoretical maximum values (Jaric, 2015). Therefore the power production is maximized at submaximal force and velocity values (Lieber et al., 2017).

FV Relationship in Multi-joint Movements

It exists several other factors than cross-bridge kinetics that influence the observed FV relationship, like neural factors, elastic component, muscle architecture, lever arms of joints, and intermuscular coordination (Alcazar et al., 2019). In multi-joint movements, it has been suggested that an approximately linear relationship could exist between the force and velocity output, and this has been observed in various vertical jumps (Jaric, 2015). Regarding the linearity of the FV relationship in multi-joint movements, it has been proposed that it is influenced by segmental dynamics, and this influence is magnified by increasing movement velocity (Bobbert, 2012). When comparing exercises with different push-off distances and joint contributions, the segmental dynamic influence the theoretical maximal shortening velocity (V_0) to a greater degree than the theoretical maximal force (F_0) (Bobbert, 2012). It should be mentioned that both central and peripheral factors can influence the FV relationship, in addition to the skills of the subject regarding various loading conditions. Vertical jumps can be performed through many kinematic patterns, and the depth of the countermovement affects both the force and power output, which can alter the shape of the FV relationship (Mandic et al., 2015).

FV Characteristics in Sprinting and Jumping

The relations between FV characteristics and vertical jump performance were investigated, and it was observed that P_{max}, V_{max}, and maximum isometric force were positively correlated with vertical jumping performance ($r = 0.76, 0.48$, and 0.68, respectively; $p < 0.001$) (Yamauchi & Ishii, 2007). A study looked at associations of mechanical variables derived from the FV relationship with approach jump, linear sprint, and change of direction in young male volleyball players (Pleša et al., 2021). The results showed that jumping performance was influenced by maximal power output and force capacity ($r=0.51$ and 0.45; respectively), whereas horizontal force production ($r = 0.45$) seemed to influence sprinting performance (Pleša et al., 2021).

An investigation of important factors for sprinting found that sprint performance was limited by the ability to produce high RFD during the short ground contact times, rather than the ability to apply force (Weyand et al., 2010). Another study also found that jumping performance showed a positive correlation with RFD ($r = 0.68$) and peak force ($r = 0.41$), even though another study found that peak force may not be a great indicator for vertical jump performance (Kirby et al., 2011; McLellan et al., 2011). Newton et al (1999) found that the jump squat showed greater improvements compared to the back squat group in jumping performance, which could be explained by greater force production before take-off and a higher RFD (Newton et al., 1999).

2.6 Resistance Training for Power, Sprinting, and Jumping

2.6.1 Traditional Training

The primary aim of a strength and power training program is to shift the FV curve to the right, which in practice makes the athlete more capable to move larger loads at higher velocities and therefore increasing their RFD (Bompa & Haff, 2009). It is strongly suggested that force plays an essential part in power development, and an individual must be relatively strong to possess a high level of power (Cormie et al., 2011b). Heavy strength training has been shown to alter the FV curve, and especially the high-force portion of the curve, whereas explosive strength training has to a greater degree shown to alter the high-velocity portion, which will result in a right shift of the FV curve (Kawamori & Haff, 2004; McLellan et al., 2011). For long-term improvement, it is also important to consider movement pattern, load, and velocity specificity and use ballistic, plyometric, weightlifting, and traditional exercises (Cormie et al., 2011b). It is optimal to include sport-specific plyometric exercises to maximize the transfer to the specific sport, and the more specific it is to stretch rate and load characteristic of the sport movement, the greater is often the transfer (Sáez de Villarreal et al., 2012).

2.6.2 Individualized Training based on the FV Profile

There is tremendous individual variation and genetics plays a major role in determining the response and changes from a training program and explains why some are categorized as "high" and "low" responders (Wilmore et al., 2015). Thus, it exists a huge need for efficient methods to individualize training. Based on the belief that the relationship between force and velocity in multipoint movements linear regression can be used to assess the athlete's (F_0), and V_0 (Jaric, 2015). This can be used to determine the individual ratio between force and velocity, and P_{max} which is shown in the slope of the FV profile (Samozino et al., 2014).

It is suggested that it exists an optimal FV profile (Figure 2) for maximizing jumping performance for each individual and that athletes with similar theoretical P_{max}, but different FV profiles can vary in jumping performance (Samozino et al., 2011). Multiple studies have shown that reducing the FV_{imb} improves jumping performance without increasing P_{max}, and stated that this approach can be useful when individualizing training (Álvarez et al., 2020; Jiménez-Reyes et al., 2017; Simpson et al., 2021). It should be mentioned that these promising results have not been demonstrated in later studies. Rakovic et al. (2018) found that an individualized training program based on the horizontal FV profile was no more effective than a generalized sprint-training program. Furthermore, Lindberg et al. (2021c). failed to demonstrate the promising results and found no significant changes in jumping and other performance measures.

Explosive strength training has to a greater degree shown to alter the high-velocity portion, which will result in a right shift of the FV curve (Kawamori & Haff, 2004; McLellan et al., 2011). For long-term improvement, it is also crucial to consider movement pattern, load, and velocity specificity and use both ballistic, plyometric, weightlifting, and traditional exercises (Cormie et al., 2011b). It is optimal to include sport-specific plyometric exercises to maximize the transfer to the specific sport, and the more specific it is to stretch rate and load characteristics of the sport movements, the greater is often the transfer (Sáez de Villarreal et al., 2012).

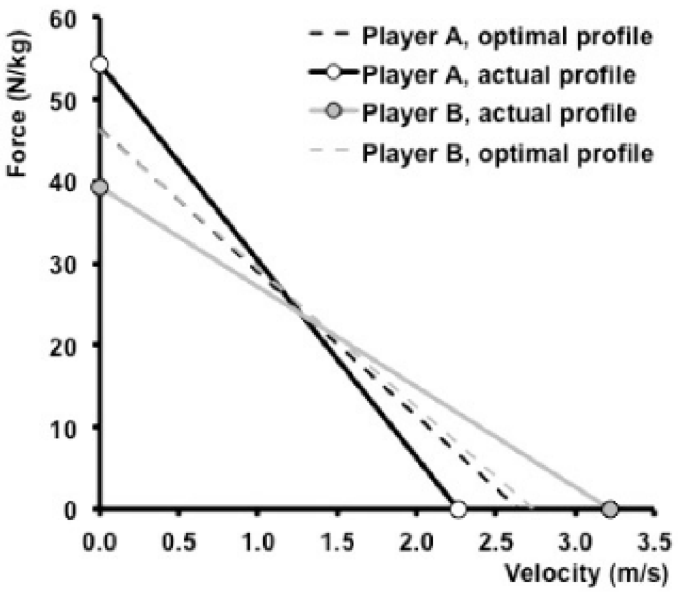

FIGURE 2 A visual picture of the actual and optimal FV profiles of two athletes. Player A is force dominant and Player B is velocity dominant (Morin & Samozino, 2016).

2.7 Complications with the FV profile

Performing vertical jumps with additive loads is often used to determine the FV profile (García-Ramos et al., 2019). There are several reasons why this method has relatively poor reliability, and a limitation with this method is the technical demands of vertical jumping with high loads, and therefore measurements close to F_0 are not optimal (Lindberg et al., 2021b; Wade et al., 2019). In addition, bodyweight is the lightest assessable load, and therefore the highest measured velocity would generally be far from V_0 (García-Ramos et al., 2017; Lindberg, et al., 2021b) Optimally, measurements close to both F_0 and V_0 should be included when determining the FV profile, since measurements far away from these can lead to inaccurate estimates of F_0 and V_0, which might negatively influence the reliability and validity of the slope and P_{max} (Cuk et al., 2014; Jiménez-Reyes et al., 2014). Using the Keiser Pneumatic Leg Press device has shown to give valid measurements over a wide range of forces and velocities and across different devices (Lindberg et al., 2021a). The FV variables obtained from average force and velocities values showed trivial systematic bias with low random errors and should therefore be preferred over peak values (Lindberg et al., 2021a). When looking at test-retest reliability, the vertical jump showed poor reliability for the V_0 and the slope of the FV profile, while the leg press displayed acceptable reliability for all variables. This can be due to better standardization in terms of fixed seat position, which in practice means less technical variation between the subjects (Lindberg et al., 2021a). A larger load range also reduces the need for extrapolation for both force and velocity, which explains the high reliability of all the FV variables. In vertical jump, the extrapolated variables V_0 and the slope of the FV profile are most likely influenced by extrapolation error, in addition to technical and biological variations (Lindberg et al., 2021a).

As mentioned earlier the FV relationship is different in single muscle fibers and multi-joint movements. As the FV profile is measured from system velocity and ground reaction forces, it is influenced by many factors which are unrelated to muscular properties, such as moment arms, joint angles, push-off distances, bodyweight, anthropometrics, and segmental dynamics (Samozino et al., 2011). This makes the FV profile unpredictable.

Another complication with this method is the uncertainty around the other valuable performance variables when training after the FV_{imb} (Lindberg et al., 2021c). This is important since athletic performance is dictated by other performance variables than jumping, such as stops, sprinting, sideway high-intensity movements, changes of directions, and one-on-one situations (Póvoas et al., 2012).

2.8 Summary

The research shows that handball and football performance relies on the player's physical capabilities and that the ability to jump, sprint, and produce power is essential to perform at a high level (Haugen et al., 2014; Póvoas et al., 2012). Sprinting and jumping are often performed previous to a goal in both sports, which emphasizes the role of these (Faude et al., 2012; Póvoas et al., 2012). These abilities are affected by multiple factors, but the ability to produce force rapidly (RFD) is a common and crucial determinant for both, due to the short ground contacts during these movements (McLellan et al., 2011). RFD is affected by both muscle, morphological and neural factors, and should all be aimed to improve during a power training period (Cormie et al., 2011b). This can be done through a traditional power training program, which aims to improve these through different exercises with various loading and repetition schemes (Cormie et al., 2011b). Due to large individual variation, an individualized power training program can be optimal, and therefore the training based on the theoretical individual FV profile was created (Samozino et al., 2011). However, this method has demonstrated conflicting results and multiple complications, and should therefore be investigated further (Jiménez-Reyes et al., 2017; Lindberg et al., 2021c).

3.0 Method

3.1 Study design

This study was completed as a randomized controlled trial (RCT), where the participants were familiarized with the testing procedures, followed by a pre-test, a 10-week training period, and a post-test thereafter. Test personnel was present during the testing, which ensured that the test protocol went according to plan. Ahead of the intervention, the subjects had a familiarization session that aimed to maximize the training effect, minimize the injury risk, and reduce a potential learning effect. Due to the nature of the study, the study was completed non-blinded.

The theoretical individual FV- profile was obtained from an incremental loading protocol during the SJ, and Samozino's method was performed (Morin & Samozino, 2016). To determine the individual profile, the athlete's body mass, lower-limb length (when fully extended), starting height, and jump height were applied. Stratified randomization allocated the subjects to an individualized (n=20) or a balanced (n=20) training group, and the FV_{imb} determined which capability the subjects in the individualized training group should focus on, where they were either defined as force or velocity dominant (Table 1). The training method is based on the principle that the athletes focus on their weak ability, which in practice meant that the force dominant athletes work on velocity and vice versa. Specifically, they were placed to either conduct heavy strength training, high-velocity training, or a combination of these in the balanced training group (Table 3). When the jumping measurements were done the FV profile could be completed (Morin & Samozino, 2016). The cut-off for FV deficits was set according to the FV profile in % of optimal: <90% and >110% for force and velocity deficits, and 90-110% were considered well-balanced (Jiménez-Reyes et al., 2017). The pre-test showed that the entire group was velocity dominant.

TABLE 1 Training Groups

Balanced	**Individualized Velocity dominant**	**Individualized Force dominant**
Subjects focus on improving both force and velocity	Subjects focus on improving their force characteristics	Subjects focus on improving their velocity characteristics

Note: The cut-off for FV deficits was set according to the FV profile in % of optimal: <90% and >110% for force and velocity deficits, and 90-110% was considered as well-balanced. Velocity dominant program: Mostly exercises with low velocity and high loads. Force dominant program: Mostly exercises with high velocity and low loads. Balanced program: Combination of both types of exercises.

3.2 Subjects

A total of 40 athletes participated (age 22 ± 4 years, height 183 ± 10 cm, and body mass 84 ± 15 kg). The athletes were elite national-level team sports players in handball and football. The baseline characteristics of the subjects are presented in Table 2, showing no significant baseline differences between training modalities ($p < 0.05$).

TABLE 2 Subject characteristics

Characteristic	Balanced	Individualized
Sample size (n)	20	20
Men/Woman	16/4	15/5
Age	22.3 ± 4.2	21.6 ± 3.6
Height (cm)	184.3 ± 9.4	182.1 ± 10.5
Weight (kg)	85 ± 15.0	83.2 ± 16.0

Note: Values are presented as mean ± SD. Cm, centimeter; Kg, kilograms; SD, standard deviation.

The subjects were recruited during the spring and summer of 2021 by contacting the representative elite football and handball clubs. They were informed both orally and in writing about the study. Inclusion and exclusion criteria were prescribed (Table 3. They voluntarily took part in the study and could withdraw whenever and without any specific reason. We tested 83 subjects, and 40 of them met the criteria and joined the study. They were informed about the risks who are associated with resistance training. although the injury risk of resistance training is quite small compared to sports like football and handball (Keogh & Winwood, 2017)

TABLE 3 List of inclusion and exclusion criteria for participation

Inclusion criteria	Exclusion criteria
1. National elite athletes	1. Medical drugs
2. Part of an elite handball or football team	2. Illnesses or injuries who prevent them from safe participation
	3. Less than 75% attendance at training sessions

The study was approved by the Norwegian Centre for Research Data and permission to complete this master thesis was granted by the local ethics committee for the Faculty of Health and Sport Science at the University of Agder. It has been conducted in accordance with the Declaration of Helsinki. It was obtained written consent from all the subjects.

3.3 Training intervention

The training intervention lasted for ten weeks with three workouts per week. It was prescribed 30 sessions during the training period and split into three different days which were customized for each athlete based on which group they were placed in. Since all the subjects were defined as velocity dominant, the individualized group focused on their force-producing ability, which means a high absolute (heavy loading) and relative intensity (Table 4). The theoretical force dominant group was supposed to focus on velocity with light loading (Table 5). The balanced training group focused on both force and velocity, which means that they trained with both heavy and light loading, with varying degrees of relative intensity (Table 6). To control the relative intensity of the exercises the subjects used a method called "repetitions in reserve" or RIR. If the athlete should perform ten repetitions with 1-2 RIR, a weight where the athlete can maximum perform 12 repetitions should be applied (Helms et al., 2016). Over the training period, the intensity increased as the training volume decreased, which is common when aiming to improve neurological abilities.

TABLE 4 Individualized Power Training Program (Force)

	Repetitions x Sets				
Session 1:	**Session 1-3**	**Session 4-6**	**Session 7-9**	**Load (RIR)**	**Rest**
Deadlift	8 x 3	6 x 3	3 x 3	1-2 RIR	2-3 min
Single leg hip thrust	8 x 3	6 x 3	3 x 3	1-2 RIR	2-3 min
Bulgarian split squat	8 x 2	6 x 2	3 x 2	5-6 RIR	2-3 min
Front squat	8 x 2	6 x 2	3 x 2	1-2 RIR	2-3 min
Trap bar with low handle	5 x 2	5 x 2	5 x 2	70% 1RM	3-4 min
Session 2:	**Session 1-3**	**Session 4-6**	**Session 7-9**	**Load (RIR)**	**Rest**
Squat	8 x 2	6 x 2	3 x 2	1-2 RIR	2-3 min
Single leg deadlift	8 x 2	6 x 2	3 x 2	1-2 RIR	2-3 min
Bulgarian split squat	8 x 2	6 x 2	3 x 2	5-6 RIR	2-3 min
Trap bar with low handle	5 x 2	5 x 2	5 x 2	50% 1RM	3-4 min
Single leg calf raises	10 x 2	10 x 2	10 x 2	5-6RIR	1-2 min
Session 3:	**Session 1-3**	**Session 4-6**	**Session 7-9**	**Load (RIR)**	**Rest**
Bench press	8 x 3	6 x 3	3 x 3	1-2 RIR	2-3 min
Weighted pull ups	8 x 3	6 x 3	3 x 3	1-2 RIR	2-3 min
Pullover	8 x 3	6 x 3	3 x 3	1-2 RIR	2-3 min
Incline bench press	8 x 2	6 x 2	3 x 2	1-2 RIR	2-3 min
Single arm rows	8 x 2	6 x 2	3 x 2	1-2 RIR	2-3 min
Shoulder press	8 x 2	6 x 2	3 x 2	1-2 RIR	2-3 min

Abbreviations: RIR, repetitions in reserve; 1RM, one-repetition maximum; Min, minute; Sets, training sets; Kg, kilograms.

TABLE 5 Individualized Power Training Program (Velocity)

	Repetitions x Sets				
Session 1:	**Session 1-3**	**Session 4-6**	**Session 7-9**	**Load (RIR)**	**Rest**
Half squats	8 x 3	5 x 3	3 x 3	1-2 RIR	2-3 min
Banded squat jumps	5 x 3	5 x 3	5 x 3	Negative	3-4 min
Trap bar jumps with low handle	5 x 2	5 x 2	5 x 2	50% 1RM	3-4 min
Step ups	5 x 2	5 x 2	5 x 2	10-20 kg	3-4 min
Single leg hip thrust	8 x 3	5 x 3	3 x 3	1-2 RIR	2-3 min
Session 2:	**Session 1-3**	**Session 4-6**	**Session 7-9**	**Load (RIR)**	**Rest**
Banded squat jumps	5 x 3	5 x 3	5 x 3	Negative	3-4 min
Trap bar jumps with low handle	5 x 2	5 x 2	5 x 2	50% 1RM	3-4 min
Box jumps	5 x 2	5 x 2	5 x 2	Body weight	3-4 min
Clean pull	5 x 2	5 x 2	5 x 2	50% 1RM	3-4 min
Stair jumps	5 x 2	5 x 2	5 x 2	Body weight	3-4 min
Session 3:	**Session 1-3**	**Session 4-6**	**Session 7-9**	**Load (RIR)**	**Rest**
Medicine ball chest throws	5 x 3	5 x 3	5 x 3	4-6 kg	2-3 min
Single arm row	8 x 3	6 x 3	3 x 3	5+RIR	2-3 min
Overhead medicine ball throw	5 x 3	5 x 3	5 x 3	4-6 kg	2-3 min
Bench press	8 x 2	6 x 2	3 x 2	1-2 RIR	2-3 min
Explosive pull ups	5 x 2	5 x 2	5 x 2	Body weight	2-3 min
Launching push ups	5 x 2	5 x 2	5 x 2	Body weight	2-3 min

Abbreviations: RIR, repetitions in reserve; 1RM, one-repetition maximum; Min, minute; Sets, training sets; Kg, kilograms.

TABLE 6 Balanced Power Training Program

	Repetitions x Sets				
Session 1:	**Session 1-3**	**Session 4-6**	**Session 7-9**	**Load (RIR)**	**Rest**
Deadlift	8 x 3	6 x 3	3 x 3	1-2 RIR	2-3 min
Front squat	8 x 2	6 x 2	3 x 2	1-2 RIR	2-3 min
Bulgarian split squat	8 x 2	6 x 2	3 x 2	5-6 RIR	2-3 min
Single leg hip thrust	8 x 3	6 x 3	3 x 3	1-2 RIR	2-3 min
Trap bar jump with low handle	5 x 2	5 x 2	5 x 2	50 % 1RM	2-3 min
Stair jumps	5 x 2	5 x 2	5 x 2	Body weight	2-3 min
Session 2:	**Session 1-3**	**Session 4-6**	**Session 7-9**	**Load (RIR)**	**Rest**
Banded squat jumps	5 x 3	5 x 3	3 x 3	Negative	3-4 min
Trap bar jumps with low handle	5 x 2	5 x 2	3 x 2	50% 1RM	3-4 min
Box jumps	5 x 2	5 x 2	3 x 2	Body weight	3-4 min
Stair jumps	5 x 3	5 x 3	3 x 3	Body weight	2-3 min
Single leg jumps in stair	10 x 2	10 x 2	5 x 2	Body weight	1-2 min
Deadlift	8 x 3	6 x 2	4 x 3	1-2 RIR	2-3 min
Session 3:	**Session 1-3**	**Session 4-6**	**Session 7-9**	**Load (RIR)**	**Rest**
Bench press	8 x 3	6 x 3	3 x 3	1-2 RIR	2-3 min
Single arm row	8 x 3	6 x 3	3 x 3	1-2 RIR	2-3 min
Pull over	8 x 3	6 x 3	3 x 3	5 RIR	2-3 min
Incline bench press	8 x 2	6 x 2	3 x 2	1-2 RIR	2-3 min
Explosive pull ups	5 x 2	5 x 2	5 x 2	Body weight	2-3 min
Launching push ups	5 x 2	5 x 2	4 x 3	Body weight	2-3 min

Abbreviations: RIR, repetitions in reserve; 1RM, one-repetition maximum; Min, minute; Sets, training sets; Kg, kilograms.

3.4 Test procedure and measurements

Testing was performed indoors. Body mass was measured wearing training clothes and shoes. A standardized ∼10-minute warm-up procedure was performed before the testing. Breaks were given between the tests to ensure proper recovery. The test protocol included a CMJ, a 20-m sprint test, and a Keiser leg press, which will be explained later. Since the study is a part of a larger research project, the subjects also performed several other tests: Dual-X-ray absorptiometry (General Electric Company, Madison, USA), Ultrasound (LogicScan 128 CEXT – 1Z kit, Telemid, Vilnius, Litauen), Squat 1-repetition maximum, Bench press Power profile (Musclelab Encoder, Langesund, Norge). Since these are not a part of this study, they are not explained further.

Keiser Leg press

A Keiser Leg press A300 is a pneumatic resistance-based seated leg press machine that consists of two separated footplates that move independently of each other.

Before the test, the athlete's 1RM was estimated and a 10-step test was performed with incremental loads based on the estimate. The seating position was adjusted to secure a vertical femur and the knee angle was set to around 90˚ for every subject. The settings were noted so the same procedures were performed in the pre-and post-test. Subjects were instructed to perform the test with maximal intent and move the load as hard and fast as possible in the concentric part of the movement. Before the test, they performed some warmup sets at the lightest load (∼15 of 1RM), and from there the load increased from the first to the last repetition until muscular failure and 1RM were reached. As the loading increased, so did the rest periods, which varied from 10-40 seconds. The Keiser Leg press recorded the peak force, velocity, and power for both legs in every single repetition (Redden et al., 2018).

20-meter sprint test

A 20-m sprint test (1080 Quantum Sprint Motion AB, Stockholm, Sweden) measured the subject's sprint performance. Photocells measured the time every five meters of the test, which can be used to look at the subject's acceleration and top speed. Muscle lab (Ergotest Innovation AS, Stathelle, Norway) was used and made it simple to have an overview of the whole test. Some of the subjects were tested in other places than Kristiansand and were tested with a Dual-Beamed Timing System (Biorun, Biomekanikk AS, Oslo, Norway) and with a wall-mounted photogate system (IC Control Tracktimer). The subjects performed a pair of warm-up runs before the test started, and before the test, they were instructed to increase the speed throughout the whole test since many unconsciously slows down the pace before the last sensor. The trial started when the subject's foot left the start line and activated the sensors, and it was not allowed to have a countermovement before they started to run. The participants performed 2-4 runs with 3-4 minutes of recovery time between each run, where the best trial was used for further analysis.

Vertical jump test

The vertical jump test was used to determine the theoretical individual FV profile and to measure the subject's jumping performance. They performed both CMJ and SJ with additional loads and were instructed to stand straight in the middle of the force plate. The CMJ was completed with the hands on the hip, but the individual could choose their preferred squat depth. The subjects performed two to three jumps before the test started to become comfortable with the test. From there, they completed four sets: two sets of three CMJ with bodyweight, three SJ with 40 kilograms (kg), and two SJ with 80 kg. Subjects with a lower strength performed the two last jumps with 60 to 70 kg. If the jump was over 15 cm, they performed another jump with heavier loads. Between the sets, they had three to five minutes of recovery, and 10-20 seconds between each jump. The tests were completed on an adjusted squat rack and with a force plate (AMTI; Advanced Mechanical Technology, Inc Waltham Street, Watertown USA) to measure jump height (cm), mean force (N), velocity (m/s), and power (W). Some subjects were assessed with another force place (Kistler Instrumente AG, type Kistler 9286BA).

3.5 Statistical analysis

Descriptive statistics expressed the characteristics of the subjects at baseline. To present the data at baseline, mean and SD were used (Table 4). After investigating the mean, median, skewness, and kurtosis the data were concluded to be normally distributed. A paired sample t-test was therefore used to analyze within-group pre to post changes, and statistics on percentage change were performed. In addition to the p-value, the results were presented as percentage mean, standard deviation, and 95% confidence interval. (Table 4). The between-group changes were investigated using an independent sample t-test and the results were presented as percentage mean, p-value, and confidence interval (Table 4). Confidence limits for all analyses were set at 95% and the significance level at <0.05. All statistical analyses were performed using IBM statistical package (version 25; SPSS Inc).

4.0 Methodological discussion

4.1 Study design

The present study was conducted as a randomized controlled trial (RCT), which is performed under controlled conditions with random allocation of intervention to comparison groups (Bhide et al., 2018). Evidence obtained from an RCT is considered the highest quality, and the RCT is seen as the most systematic and reliable method to assess whether a cause-effect relationship exists between an intervention and an outcome (Bhide et al., 2018). The evidence that is obtained from observational data is prone to bias, which is defined as the systematic tendency of any factors associated with the design, conduct, analysis, evaluation, and interpretation of the results to estimate the effect deviates from its true value (Bhide et al., 2018). The randomization reduces bias by balancing the subjects' characteristics between the groups, which allows attribution of any differences in outcome to the study intervention (Hariton & Locascio, 2018). An issue with the RCT is the challenge of generalizing, where the subjects may not be representative of the population the study wants to investigate (Hariton & Locascio, 2018). This should be considered an important criterion when designing an RCT, and the answers that are provided apply to the patient population similar to that used in the trial, and extrapolation of the results to other patients is not strictly valid (Bhide et al., 2018). The Hawthorne effect should also be mentioned, where the subjects are aware of being studied and therefore potentially changes behavior and therefore obscure the effect of the training intervention (McCambridge et al., 2014).

This study did not include a non-training control group, which potentially could allow for an examination of what changes were caused by the intervention and what changes were not (Polit & Beck, 2017). Since the subjects were in-season, maintenance of physical capabilities is essential, and a non-training group could have given valuable information and provided an important comparison to the training groups (Polit & Beck, 2017). This can be considered a weakness of the study.

The FV profiling in this study resulted in velocity dominant athletes, only. Therefore, an individualized training group that performed high-velocity power training was not included.

Optimally, the FV profiling would prescribe force dominant athletes as well, so the comparison would be from two sub-groups in the individualized training group and the balanced training group. In reality, the individualized training group was just a heavy strength training group, which makes the comparison of the two intervention groups weaker, and can be seen as a large limitation. Due to this, it can be speculated that the FV profiling is unreliable and should be discussed further.

Blinding can help to eliminate unconscious information bias, but since this was a non-blinded study, both subjects and investigators knew which training group the subjects were placed in (Bhide et al., 2018). Due to the nature of the study, it was impossible to blind the subjects or/and the investigators, and can be seen as a weakness.

4.2 Study Sample

This present study is a part of a larger research project, and the main project calculated (G*power 3.1.9.2) that a minimum of 34 subjects were needed to detect a significant group difference. In similar studies and analyzes, SD is commonly used to look at primary outcomes, which in this study were CMJ and 20-m sprint. Based on the effects of earlier research, the power analysis suggests expected between-group differences, and an 80% statistical power is regularly applied, which states that there is an 80% chance to detect existing between-group differences. The p-value was set to <0.05, which states that it is a 1:20 chance that a type I error could occur (Bhide et al., 2018).

40 (n=40) elite handball or football athletes took part in the present study. 71 subjects were obtained for the training intervention, and 31 of them dropped out during the training intervention due to various reasons. In general, the more widely the two groups are separated from each other and the smaller the variability in each group, the fewer subjects are necessary to show that the potential difference from pre-to post-test is due to the intervention (Bhide et al., 2018). The high number of participants increased the chances that a significant treatment benefit could be detected and that a type II error would not occur (Bhide et al., 2018).

4.3 Training Intervention

The training intervention went over 10 weeks, whereas previous studies have shown that a training period of 9 weeks both improved jumping performance and reduced the FVimb (Jiménez-Reyes et al., 2017). Therefore, a training program that lasted over 10 weeks is considered sufficient. Each week, three strength training sessions were prescribed in addition to sport-specific training organized by the team. When resistance training is equated to weekly training volume, the training frequency has shown not to matter in strength gains (Ralston et al., 2018). This assured that the training frequency was adequate to provide improvements. Earlier research has shown that both heavy and light loading could potentially improve measurements like jumping and sprinting performance (Hackett et al., 2016; Mangine et al., 2008; Ronnestad et al., 2008). Thus, one could imagine that both groups could potentially show improvements. The resources of this study were not sufficient to follow the subjects during each workout. To estimate to load they were supposed to use the RIR method (Helms et al., 2016). It can be an appropriate method for estimating training load in the high-force end of the power spectrum (Helms et al., 2016). Even though it has been observed that RIR is often overestimated and it is therefore possible that some subjects could not reach the relative intensity that was intended (Halperin et al., 2022). Ideally, training instructors should be present to secure the relative intensity and can therefore be considered a weakness of this study. It is also difficult to use RIR efficiently at the high-velocity end of the power spectrum (Helms et al., 2016). Thus, high-velocity exercises were prescribed with a percentage of 1RM. It should therefore be mentioned that it exists complications with these. Optimally, these movements should be performed close to $V_{max,}$ and since bodyweight is the lightest available load, this cannot be done effectively (García-Ramos et al., 2019). This issue can partly be solved with negative resistance using elastic bands, but it can be thought that this method is far away from V_{max} as well, but this remains just speculation. When using machines and traditional exercises the athlete needs to decelerate at the end of the concentric movement, which is associated with reduced agonist activation (Newton et al., 1996). Machines are also exposed to being broken when performing high-velocity training, but this can be sorted out with pneumatic resistance machines, that are designed to perform high-velocity training in a safe environment (Balachandran et al., 2017). An issue is that these are expensive and access to them is limited (Balachandran et al., 2017).

4.4 Measurements

Valid and reliable performance assessments in sports are heavily dependent upon standardized procedures and precise equipment (Haugen & Buchheit, 2016). The most relevant issue regarding the data collection and the measurement methods is the data quality, which is affected by both reliability and validity (Thomas et al., 2015). Reliability is defined as the degree of consistency of the test and how repeatable it is, and validity is defined as the degree to which a test measures what it is supposed to (Thomas et al., 2015). When evaluating individual data of high-performing athletes, the test-retest reliability and within-subject variation are considered essential to observe true changes in performance (Hopkins, 2000; Hopkins et al., 2001). The coefficient of variation (CV%) is often used to assess reliability across testing sessions, where acceptable reliability is considered as CV ≤ 10% and good as CV ≤ 5% (Lindberg et al., 2021b). It is important to control the working conditions and perform similar pre-and post-test procedures (Thomas et al., 2015). Before the intervention, the subjects had a familiarization session, which aimed to reduce and minimize the possible learning effect and therefore increase measuring reliability. The testing protocols were standardized to a large degree through similar procedures for both pre-and post-test to increase reliability, which was also conducted in previous research (Lindberg et al., 2021c). During the tests, the test personnel encouraged the subjects to perform and push themselves through cheering and verbal motivation, and to secure maximal performance output. It can be speculated that the degree of verbal motivation varied from subject to subject and could have an impact on the results.

Vertical jump test with a force plate (CMJ and SJ)

The peculiarity of the vertical jump test is the possibility to obtain the extrapolated variable V_0 and the calculated slope of the FV profile since multiple other tests could obtain maximal force and power (Abernethy et al., 1995). Lately, the vertical jumping has shown poorer reliability in obtaining V_0 and the slope of the FV profile, than F_0 and P_{max} (Feeney et al., 2016). García-Ramos et al. (2017) suggested that the low V_0 reliability during vertical jumping was due to the distance of extrapolation to the V_0 intercepts as the lightest load possible to evaluate is the subject's body weight, while attempts closer to F_0 were limited by the subject's ability to jump with heavy loads. Meylan et al. (2015) speculated that biological variation close to V_0 can affect the reliability of the V_0, but this speculation was questioned by Lindberg et al. (2021b) who found similar typical errors across loads and V_0 and F_0. It has been observed that measures for P_{max} and F_0 obtained from vertical jumps showed acceptable reliability with the CV ranging from 3.9 to 12.1% (Lindberg et al., 2021b). However, V_0 and the slope showed unacceptable reliability with the CV% ranging from 8.4 to 30.1%. It can be speculated that this is due to both extrapolation error and the combination of technical/instrumental and biological variations (Lindberg et al., 2021b).

Potentially, this unacceptable reliability could lead to inaccurate FV profiling, which can explain the absence of force-dominant athletes. The lack of force dominant athletes corresponds to the findings of Álvarez et al. (2020), where a group of ballet dancers showed a force deficit, only. This was explained by the peculiarity of ballet and the limited focus on resistance training (Álvarez et al., 2020). Handball and football are characterized by jumping, sprinting, changes of directions, and SSC actions, but the emphasis on resistance training is greater than in ballet, whereas elite handball athletes have shown great strength capabilities (Gorostiaga et al., 2005; Wagner et al., 2018). Thus, the argument of Álvarez et al. (2020) is not valid for this study. Instead, it can be speculated that the FV profiling is inaccurate due to complications with the vertical jump test method (Lindberg et al., 2021b). Potentially, the athlete could have been prescribed with the wrong deficit, which could have affected the progress of the subjects negatively.

The results from the CMJ were used to measure the subjects jumping performance progress. Jump height has been observed to exhibit an acceptable level of reliability with a CV of 5.8% (Souza et al., 2020). The CMJ has shown better test-retest reliability than the SJ, possibly because that jumping with a counter-movement is more natural and familiarized (Bobbert et al., 1996).
The subject chose both the starting position and the squat depth. Since the athlete's jumping ability is affected by vertical impulse produced into the ground the depth of the squat could affect the jumping performance (Kirby et al., 2011; Winter, 2005). Increasing squat depth allows the muscles to exert force for a longer duration of time and increases the relative vertical impulse, and therefore enhances jumping performance (Kirby et al., 2011). This was demonstrated by McBride et al. (2010) where changing the squat depth caused a ~5% variation in jump height. This can be seen as a limitation of the study and should be controlled more accurately in further research.

Keiser Leg Press

Measurements of lower limb strength and power in the Keiser Leg Press are a reliable and valid method (Redden et al., 2018). It can be assumed that the reliability of the test is high when measuring extrapolated variables such as the F_0, V_0, and the P_{max} (Lindberg et al., 2021b). The test is not limited by the technical demands such as the vertical jump test and can therefore obtain data close to F_0. It can also be obtained values closer to V_0 since the "bodyweight issue" from the vertical jump test is not present during the leg press. It is also uncomplicated to standardize the exercise in form of a fixed seat position, which increases the reliability of the test method (Lindberg et al., 2021b). In terms of this study, the subjects performed the test with the same seat position on both tests. In addition to great standardization opportunities, the Keiser Leg Press reduces the need for extrapolation in both ends of the FV spectrum through the large load range. Thus, when looking at between-session reliability the Keiser Leg Press has shown acceptable and good reliability for the four FV variables (F_0, V_0, P_{max}, and the slope of the FV profile), where CV ranged from 4-8% (Lindberg et al., 2021b). In addition, an investigation of the validity of the Keiser Leg Press found that valid measurements could be obtained over a wide range of forces and velocities (Lindberg et al., 2021a). Therefore, the obtained results from the Keiser Leg Press can be seen as valid and reliable, and further research should consider using the Keiser Leg Press to obtain the individual FV profile.

20-m sprint

The 20-m sprint test was performed to measure the subject's progress in sprinting performance. It was used dual-beamed photocells, where both beams have to be broken to ensure time triggering (Haugen & Buchheit, 2016). This method has shown a 1.4% CV for 20-m sprint times, which makes the test highly reliable (Haugen et al., 2014).

The test was completed indoors, which is positive since uncontrolled factors like wind, altitude, temperature, barometric pressure, and humidity did not affect the results (Haugen & Buchheit, 2016). The surface is comparable to the surface of a handball court, which is positive since many of the subjects were handball players and were familiar with it. This reduces the potential learning effect and increases the reliability of the test. In addition, the subjects decided when to start the test, which removes the influence of the subject's reaction time (Haugen & Buchheit, 2016). To create a great impulse a large force needs to be applied, which promotes greater momentum and a high-power output (Taber et al., 2016). This force needs to be applied to the ground, and therefore it can be speculated that the friction between the subject's footwear and the ground is essential to produce force in an efficient manner (Taber et al., 2016). An optimal shoe bending stiffness has also shown to increase performance by a small margin and the performance could have been affected by the subject's clothing, and principally by its weight (Haugen & Buchheit, 2016). It was not secure that the subjects wore the same outfit at pre-and post-test, which could have affected the results and should therefore be seen as a limitation of this study. Another limitation was that some trials were unable to be measured due to problems with the lower placed photocell at the start. It can be speculated that some subjects lost their best trial due to this. To equalize this the subjects performed another trial with a longer rest to minimize fatigue and optimize performance.

6.0 Main strengths and limitations

The main strengths of this present study were a solid study design, which allowed to examine whether a cause-effect relationship existed between the intervention and the outcome. The sample size (n=40) was sufficient to detect a significant group difference and was representative of in-season elite athletes. Testing protocols were similar to previous research and standardized to a large degree, and the tests were performed with identical measurements and test leaders, which led to increased reliability.

The main weaknesses of this study were that the vertical jump has shown poor reliability in obtaining V_0 and the slope of the FV profile, which could have resulted in force dominant athletes, only. It was not included a non-training control group, which could have provided an important comparison to the training groups. The squat jump depth and the testing outfits were not standardized from pre- to post-test and could have affected the results. Additionally, it existed a photocell problem, that could have led to the athletes missing their best attempt during sprinting.

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PART 2

RESEARCH PAPER

Individualized Power Training Based on the Theoretical Force-Velocity Profile: Efficient or too many pitfalls?

The following paper is written according to the standards of the journal:
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Abstract

The present study aimed to examine if an individualized power training program based on the theoretical individual force-velocity (FV)- profile is superior to a balanced power training program to enhance jumping and sprinting performance. Forty national elite level athletes (age 22 ± 4, height 183 ± 10, and body mass 84 ± 15) from handball and football completed a 10-week training intervention. A theoretical optimal individual squat jump (SJ)-FV-profile was created from SJ with various loads (0,20,40,60.80 kg), and based on their actual FV-profile they were categorized as either force or velocity dominant. The athletes were randomized to train toward (individualized) or irrespective (balanced) of their theoretical optimal FV profile, and they were assigned training programs accordingly. The athletes performed a 20-meter sprint, SJ, countermovement jump (CMJ), and a Keiser leg-press power test before and after the training intervention. No significant changes in 20-meter sprint (-0.7% and -0.60%), CMJ (0.9% and 2.4%), maximal power output (P_{max}) (-0.1% and -1.6%), theoretical maximal force output (F_0) (-0.4% and -1.9%), theoretical maximal velocity output (V_0) (0.0% and -0.7%) and the theoretical FV-profile (-0.4% and 4.2%) were observed in either the individualized or balanced training group, respectively. No significant between-group differences were observed. The findings from this study did not support that an individualized power training program based on SJ-FV-profiling is superior to a balanced power training program.

Keywords: Resistance training, handball, soccer, force-velocity profile, running, jumping, explosive strength

1 Introduction

Handball and European football are Olympic sports that are played worldwide and at a highly professional level in many countries all over the world, and performance depends upon a variety of individual skills and interaction with their teammates.[1,2] Each player's technical and tactical skills are important determinants for performance, but the development of physical capabilities is essential to perform at the highest level.[1–3] Handball and football consist of high-intensity actions like sprinting, jumping, and changes of directions, and it is suggested that powerful players that are great at sprinting and jumping have better chances of success.[1–4] Because individuals respond differently to exercise training and there exists a large individual variation, the need for an efficient individualized training method is immense.[5] Thus, the method of individualizing training based on force-velocity (FV) profile was formed, and it is based on the concept of a theoretical optimal FV profile.[6] The optimal FV profile consists of an ideal balance between force and velocity-producing capabilities, which maximizes performance in explosive movements such as jumping and sprinting. Muscular power is a strong predictor for performance in explosive movements,[7] and it is theorized that an athlete that produces his maximal power (P_{max}) at a load greater than bodyweight is categorized as force dominant, whereas producing the theoretical P_{max} at a load lighter than bodyweight makes the athlete velocity dominant.[6] The distance between the optimal profile and the actual measured FV profile is termed FV imbalance (FV_{imb}).[6] Both theoretically and experimentally the FV_{imb} have been associated with jumping performance, which means that one can predict an athlete's jumping performance through their FV imbalance ($FV_{imb)}$ and P_{max}.[6,8]

In practice, the athlete targets its least developed capacity (force or velocity), and if an athlete is force dominant, the training program should consist of high-velocity exercises, whereas an athlete that is velocity dominant, should do more high-force exercises.[6] Initial results were promising;[8–10] however, recent research has shown conflicting results, and some questions remain unanswered.[11,12] It is uncertain if reducing FV_{imb} without changing P_{max} will improve other performance measures like 20-meter (m) sprint, countermovement jump (CMJ), and measures of power in the Pneumatic Keiser Leg Press.[7] Thus, this study aimed to investigate if an individualized power training aimed at reducing the FV_{imb} is superior to a balanced power training for improvements in jumping and sprinting performance in elite athletes.

2 Materials and Methods

Participants

A total of 40 athletes participated (age 22 ± 4 years, height 183 ± 10 cm, and body mass 84 ± 15 kg). The athletes were elite national-level team sports players in handball and football. The baseline characteristics of the subjects are presented in Table 1, showing no significant baseline differences between training modalities ($p < 0.05$).

TABLE 1 Subject characteristics

Characteristic	Balanced	Individualized
Sample size (n)	20	20
Men/Woman	16/4	15/5
Age	22.3 ± 4.2	21.6 ± 3.6
Height (cm)	184.3 ± 9.4	182.1 ± 10.5
Weight (kg)	85 ± 15.0	83.2 ± 16.0

Note: Values are presented as mean ± SD. Cm, centimeter; Kg, kilograms; SD, standard deviation.

All the subjects were informed both orally and in written form about the study. Inclusion and exclusion criteria were prescribed (Table 2) and the subjects had to meet these criteria to be included in the project. They voluntarily took part in the study and could withdraw from it whenever, without any specific reason. Written informed consent was obtained before participation. The study was approved by the ethical board of the faculty of sports science and physical education at the University of Agder, and the Norwegian Centre for Research Data, and was conducted in agreement with the Declaration of Helsinki.

TABLE 2 List of inclusion and exclusion criteria for participation

Inclusion criteria	Exclusion criteria
1. National elite athletes 2. Part of an elite handball or football team	1. Medical drugs 2. Illnesses or injuries that prevent them from safe participation 3. Less than 75% attendance at training sessions

Study Design

This study was completed as a randomized controlled trial (RCT), where the participants were familiarized with the testing procedures, followed by a pre-test, a 10-week training period, and thereafter a post-test. Test personnel was present during the testing, which ensured that the test protocol went according to plan. Ahead of the intervention, the subjects had a familiarization session that aimed to maximize the training effect, minimize the injury risk, and reduce a possible learning effect. Due to the nature of the study, the study was completed non-blinded.

To determine the individual profile, the athlete's body mass, lower-limb length (when fully extended), starting height, and jump height were applied. Stratified randomization allocated the subjects to an individualized (n=20) or a balanced (n=20) training group. The FV_{imb} determined which capability the subjects in the individualized training group should focus on, where they were either defined as force or velocity dominant (Table 1). The training method is based on the principle that the athletes focus on their weak ability, which in practice meant that the force dominant athletes worked on velocity and vice versa. More specifically, they were placed to either conduct heavy strength training, high-velocity training, or a combination of these in the balanced training group (Table 3). When the jumping measurements were done, the FV profile could be completed. [13] The cut-off for FV deficits was set according to the FV profile in % of optimal: <90% and >110% for force and velocity deficits, and 90-110% was considered as well-balanced. [8] The pre-test showed that the entire group was velocity dominant.

TABLE 3 Training Groups

Balanced	Individualized Velocity dominant	Individualized Force dominant
Subjects focus on improving both force and velocity	Subjects focus on improving their force characteristics	Subjects focus on improving their velocity characteristics

Note: The cut-off for FV deficits was set according to the FV profile in % of optimal: <90% and >110% for force and velocity deficits, and 90-110% was considered as well-balanced. Velocity dominant program: Mostly exercises with low velocity and high loads. Force dominant program: Mostly exercises with high velocity and low loads. Balanced program: Combination of both types of exercises.

The training intervention lasted for ten weeks with three workouts per week. It was prescribed 30 sessions during the training period. The programs were split into three different days which were customized for each athlete based on which group they were placed in.
The training program was inspired by similar programs which have been used in previous and comparable research and are described in table 4.[8,11] Since all the subjects were defined as velocity dominant, the individualized group focused on their force-producing ability, which means a high absolute (heavy loading) and relative intensity. The theoretical force dominant group was supposed to focus on their velocity ability with light loading. The balanced training group focused on both force and velocity abilities, which means that they trained with both heavy and light loading, with various degrees of relative intensity. To control the relative intensity in the exercises the subjects used a method called "repetitions in reserve" (RIR). This is easily used with heavy loads where the subjects are close to muscular failure, but in high-velocity movements, it does not work equally effectively. If the athlete should perform ten repetitions with 1-2 RIR, a weight where the athlete can maximum perform 12 repetitions should be applied.[14] During the training period, the intensity increased, and the training volume decreased, which is common when the goal is to improve neurological abilities.

TABLE 4 Training content for the three different training programs

Program	Exercises	Rep scheme	Load	Weekly Sets	Focus
Force	Deadlift, Single-Leg Hip Thrust, Bulgarian Split Squat, Front Squat, Squat, Single Leg Deadlift. Single-Leg Calf Raises, Bench Press, Weighted Pull-Ups, Pullover, Incline Bench Press, Single Arm Rows, Shoulder Press	3-10	1-6 RIR	33	Strength
	Trap Bar with Low Handle	5	50-70 % 1RM	4	Power
Velocity	Half Squats, Single-Leg Hip Thrust, Bench Press, Single Arm Row	3-8	1-6 RIR	11	Strength
	Banded Squat Jumps, Trap Bar Jump with Low Handles, Step-Ups, Squat Jumps, Box Jumps, Clean Pull, Stair Jumps, Single Leg Stair Jumps, Medicine Ball Chest Throw, Overhead Medicine Ball Throw, Explosive Pull-Ups, Launching Push-ups	5-10	Negative–50% 1RM	32	Power
Balanced	Deadlift, Front Squat, Bulgarian Split Squat, Single-Leg Hip Thrust, Bench Press, Single Arm Row, Pull Over, Incline Bench Press	3-8	1-6 RIR	19	Strength
	Trap Bar with Low Handle, Stair Jumps, Banded Squat Jumps, Box Jumps, Stair Jumps, Single Leg Jump in Stairs, Explosive Pull-Ups, Launching Push-Ups	4-10	Negative-50% 1RM	24	Power

Abbreviations: RIR, Repetitions in reserve; 1RM, one-repetition maximum; Rep, repetitions; Set, training sets

Testing Procedures

Keiser Leg press

A Keiser Leg press A300 is a pneumatic resistance-based seated leg press machine that consists of two separated footplates that move independently of each other.
Before the test, the athlete's 1RM was estimated and a 10-step test was performed with incremental loads based on the estimate. The seating position was adjusted to secure a vertical femur for every subject and the knee angle was set to around 90˚. The settings were noted so the same procedures were performed in pre-and post-test. Subjects were instructed to perform the test with maximal intent and move the load as hard and fast as possible in the concentric part of the movement. Before the test, they performed some warmup sets at the lightest load (~15 of 1RM). From there the load increased from the first to the last repetition until muscular failure and 1RM were reached. As the loading increased, so did the rest periods, which varied from 10-40 seconds. The Keiser Leg press recorded the peak force, velocity, and power for both legs in every single repetition.[15]

20-meter sprint test

A 20-m sprint test (1080 Quantum Sprint Motion AB, Stockholm, Sweden) was performed to measure the progress of the subjects in sprint performance. The photocells measured the time every five meters of the test, which can be used to look at the subject's acceleration and top speed. Muscle lab (Ergotest Innovation AS, Stathelle, Norway) was taken into use and made it simple to have an overview of the whole test. Some of the subjects were tested in other places than Kristiansand and were tested with a Dual-Beamed Timing System (Biorun, Biomekanikk AS, Oslo, Norway) and with a wall-mounted photogate system (IC Control Tracktimer). The subjects performed a pair of warm-up runs before the test started. They were instructed to increase the speed throughout the whole test since many unconsciously slow down the pace before the last sensor. The trial started when the subject's foot left the start line and activated the sensors, and it was not allowed to have a countermovement before they started to run. The participants performed 2-4 runs with 3-4 minutes of recovery time between each run, where the best trial was used for further analysis.

Vertical jump test

The vertical jump test was used to determine the theoretical individual FV profile and to measure the subject's jumping performance. They performed both CMJ and SJ with additional loads and were instructed to stand straight in the middle of the force plate. The CMJ was completed with the hands-on the hip, but the individual could choose their preferred squat depth. The subjects performed two to three jumps before the test started to become comfortable with the test. From there, they completed four sets: two sets of three CMJ with bodyweight, three SJ with 40 kilograms (kg), and two SJ with 80 kg. Subjects with lower strength capability performed the two last jumps with 60 to 70 kg. If the jump was over 15 centimeters, they performed another jump with heavier loads. Between the sets, they had three to five minutes of rest, and 10-20 seconds between each jump. The tests were completed on an adjusted squat rack and with a force plate (AMTI; Advanced Mechanical Technology, Inc Waltham Street, Watertown USA) to measure jump height (cm), mean force (N), velocity (m/s), and power (W). Due to the reason that some of the subjects were tested other places than Kristiansand, they were tested with another force place (Kistler Instrumente AG, type Kistler 9286BA)

3 Statistical Analysis

Descriptive statistics expressed the characteristics of the subjects at baseline. To present the data at baseline mean and SD were used (Table 1). After investigating the mean, median, skewness, and kurtosis the data were concluded to be normally distributed. The between-group changes were investigated using an independent sample t-test and the results were presented as percentage mean, p-value, and 95% confidence interval (Table 5).
A paired sample t-test was therefore used to analyze within-group pre to post changes, and statistics on percentage change were performed. In addition to the p-value, the results were presented as percentage mean, standard deviation, and 95% confidence interval (Table 5).
Confidence limits for all analyses were set at 95% and the significance level at <0,05. All statistical analyses were performed using IBM statistical package (version 25; SPSS Inc).

4 Results

At baseline, we tested 71 subjects. 31 of them dropped out during the training intervention, where 24 did not show up to the post-test, three subjects were injured or ill and four did not meet the inclusion criteria of attendance. After the pre-test 20 of the subjects were placed in the individualized training group and 20 subjects were placed in the balanced training group. No significant between-group difference in FVimb reduction was observed from pre- to post-test (Figure 1 and Table 5). None of the training groups changed their FVimb significantly from baseline (Figure 1 and Table 5).

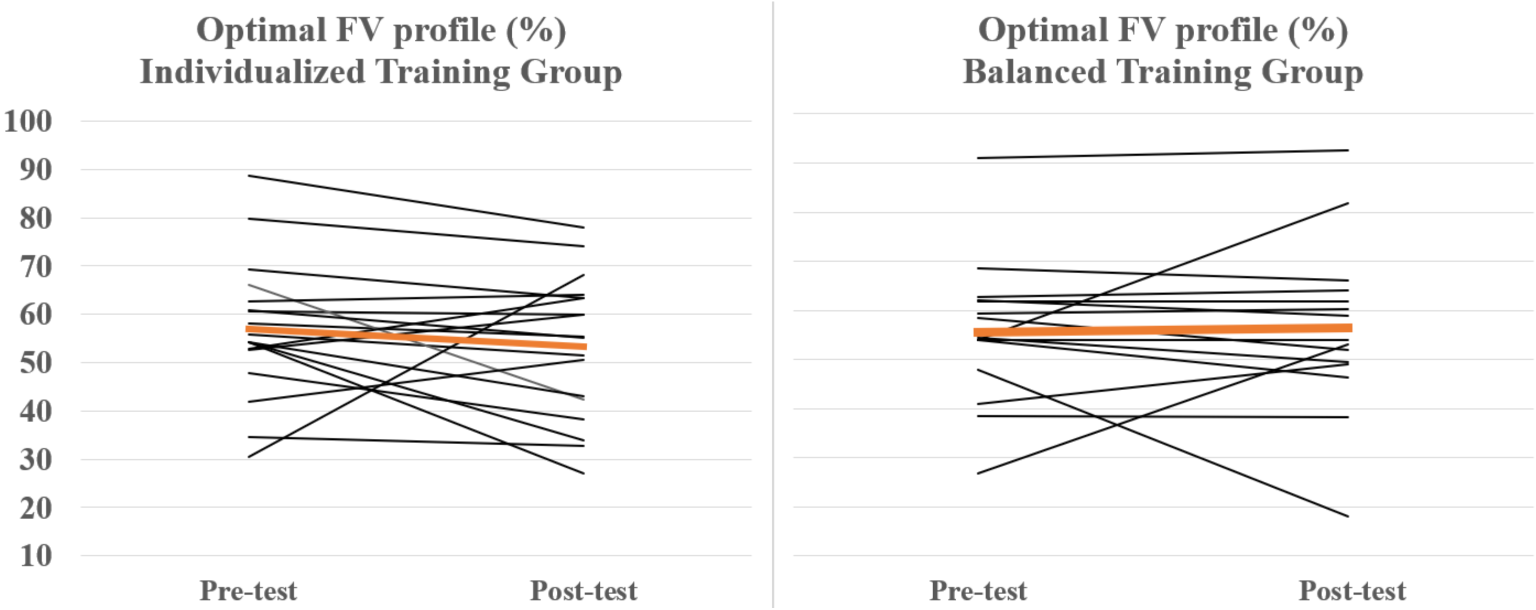

FIGURE 1 Change in FV_{imb} (%) from pre- to post-test in each subject in the individualized and balanced training group. An optimal FV profile is defined as 100%. The thick line represents the mean of each group.

It was not observed any group differences in 20-m sprint performance during the training period (Figure 2 and Table 5), and neither the balanced nor the individualized training group increased their sprint performance from baseline (Figure 2 and Table 5).
No significant differences were observed during the training period between the groups in jumping performance (CMJ) (Figure 2 and Table 5), and no significant changes were observed in the balanced or individualized training group (Figure 2 and Table 5).

There were no significant group differences from pre- to post-test in Keiser P_{max} (Figure 2 and Table 5), and neither the balanced nor the individualized training group showed significant within-group changes P_{max} (Figure 2 and Table 5). No significant between groups differences were observed in both Keiser F0 (theoretical maximal force) and Keiser V0 (theoretical maximal velocity) (Figure 2 and Table 5) There were no significant within-group changes in both Keiser F0 and Keiser V0 P_{max} (Figure 2 and Table 5).

TABLE 5 Results from the individualized and balanced training group from pre- to post-test

		Change from baseline (Paired Sample T-test)					**Between-group difference (Independent Sample T-test)**		
		Pre-test	Post-test						
Variables and groups	n	Mean ± SD	Mean ± SD	95% CI (LB, UB)	Δ% ± SD	*p*-value	Mean (%)	95% CI (LB, UB)	*p*-value
CMJ (cm)									
BAL	16	36.6 ± 5.5	37.4 ± 5.8	[-1.8, 0.1]	2.42 ± 4.97	0.380	1.49	[-2.7, 5.6]	0.471
IND	16	35.4 ± 7.3	35.7 ± 7.3	[-1.4, 0.9]	0.93 ± 6.45	0.945			
20-meter sprint (s)									
BAL	16	2.9 ± 0.2	2.9 ± 0.2	[-0.0, 0.1]	-0.60 ± 1.80	0.188	0.07	[-1.3, 1.5]	0.915
IND	17	3.0 ± 0.2	2.9 ± 0.2	[-0.0, 0.1]	-0.67 ± 2.15	0.198			
P_{max} (W)									
BAL	19	1747 ± 456	1712 ± 442	[-15.8, 86.0]	-1.64 ± 6.16	0.165	-1.5	[-5.7, 2.7]	0.470
IND	17	1555 ± 468	1542 ± 437	[-40.0, 65.5]	-0.13 ± 6.18	0.615			
Optimal FV profile (%)									
BAL	16	56.3 ± 14.4	56.7 ± 17.6	[-8.4, 7.7]	4.17 ± 35.57	0.923	4.58	[-21.9, 31.1]	0.727
IND	16	56.0 ± 14.8	53.4 ± 15.0	[-5.1, 10.4]	-0.41 ± 37.77	0.483			
F_0 (N)									
BAL	19	2715 ± 651	2651 ± 623	[-15.8, 142.0]	-1.93 ± 5.90	0.110	-1.54	[-5.3, 2.2]	0.411
IND	17	2509 ± 596	2498 ± 610	[-65.6, 86.8]	-0.39 ± 5.11	0.772			
V_0 (m/s)									
BAL	19	2.5 ± 0.2	2.5 ± 0.3	[-0.1, 0.1]	-0.67 ± 5.99	0.618	-0.67	[-5.2, 3.9]	0.766
IND	17	2.3 ± 0.3	2.3 ± 0.3	[-0.1,0.1]	0.00 ± 7.57	0.928			
Bodyweight (kg)									
BAL	20	85.0 ± 15.0	84.8 ± 14.9	[-0.2, 0.5]	-0.16 ± 0.92	0.295	-0.38	[-1.7, 0.1]	0.570
IND	20	83.2 ± 16.0	83.2 ± 15.2	[-0.8, 0.9]	0.22 ± 2.85	0.959			

Note: Mean values are presented with standard deviations (SD). Δ%: percentage change from pre- to post-test. Values for the between-group differences are obtained from the Independent Sample T-test, and within-group analyses from Paired Sample T-test. Optimal FV profile is defined as 100%. BAL, Balanced training group; IND, individualized training group; F_0, theoretical maximal force output; V_0, maximal shortening velocity. Cm, centimetre. S, seconds. W, watts. N, Newton. M/s, meters per second. Kg, kilogram

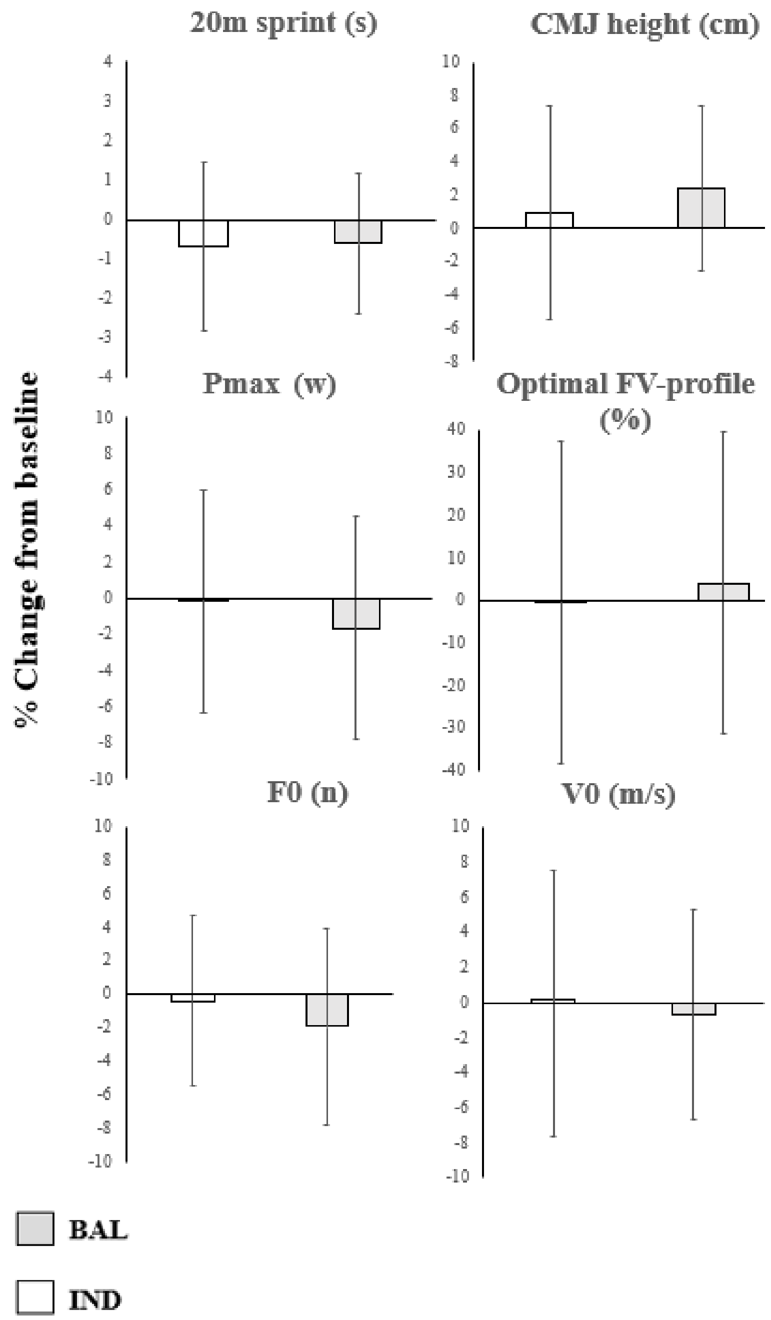

FIGURE 2 Percent change from pre- to post-test in the two groups training toward or irrespective of their initial theoretical optimal FV profile. Optimal FV profile is defined as 100%. Error bars represents 95% confidence interval. SJ, Squat jumps; Pmax, Maximal power output; F0, Maximal force output V0, Maximal shortening velocity. S, second; Cm, centimeter; W, watt; N, newton; and m/s, meter per second.

5 Discussion

This study found that prescribing a power training program based on the theoretical individual FV profile was not superior compared to a balanced training program, when aiming to improve 20-m sprint, CMJ, leg-press power, F_0, and V_0.

Samozino et al.[6] proposed the concept of training toward a theoretical optimal FV profile to increase jumping performance. Contrarily to this present study, several studies support the individualized training based on the FV_{imb} when aiming to increase the jumping ability.[8–10] None of the training groups in this present study were able to reduce their FV_{imb}, whereas the non-reduction in the individualized group is different from the mentioned studies.[8–10]
A potential reason for this can be that all subjects were defined as velocity dominant, which meant that the entire individualized group was prescribed to complete heavy strength training and focus on improving their force-producing ability. The lack of force dominant athletes corresponds to the findings of Àlvarez et al.[10] where the entire group of ballet dancers showed a force deficit. This was explained by the peculiarity of ballet, limited resistance training focus, and that the velocity ability was developed to a greater extent.[10] Whether this explanation is valid to this present study is arguable. Elite handballers have demonstrated great strength capabilities in earlier research, and when comparing elite to amateur handballers, elite players have demonstrated superior maximal leg strength and 1RM bench press.[4,16] Additionally, Hermassi et al.[17] found that first league handball players had a larger CSA and more muscle volume compared to second league players. Since it exists a proportional relationship between a single muscle fiber CSA and the capability of force production, it makes the fact that all of the subjects were categorized as velocity dominant not likely[18]. Thus, the argument of Àlvarez et al.[10] is therefore not transferable to this present study. Instead, the lower reliability of the vertical jump test could have affected the results and should be discussed further.[19]

The FV relationship differs from single muscle fibers to multi-joint movements,[20] and therefore the FV profile is influenced by factors unrelated to muscular properties such as moment arms, joint angles, push-off distance, bodyweight, anthropometrics, and segmental dynamics. [6] This makes the SJ-FV profile unpredictable and can explain the lack of velocity dominant athletes, which can be explained by the extrapolation distance as the measurements are done closer to F_0 than V_0, as demonstrated by Lindberg et al.[19]

The measurements lead to inaccurate estimates of F_0 and V_0 due to both biological variations and technical demands when jumping with heavier loads and the highest measured velocity is too far away from V_0 since bodyweight is the lightest assessable load.[19,21,22] Optimally, it should be included measurements closer to F_0 and V_0, to secure higher reliability and validity of the slope and P_{max}.[23,24] This could have been performed with a Keiser Leg Press, which has shown valid measurements over a wider range of the FV curve. [25] Potentially, the athletes could have been prescribed with the wrong deficit, which could have affected the progress of the subjects negatively. It is unclear if the athletes should focus on their weak or strong ability (force/velocity).[26] In general, it is believed that the force portion of the FV curve is easier to improve compared to the velocity portion.[27] It can be speculated that removing a stimulus that the athlete responds well to can lead to a reduced P_{max}, which will weaken both jumping and other important performance variables.[7,26,27] Additionally, the existence of the theoretical optimal FV profile must be questioned, considering that power athletes that potentially have maximized their genetic potential have shown greater jump height and also possessed FV_{imb}.[28,29]

Rakovic et al.[12] investigated in-season elite handball players and compared an individualized sprint training program based on the horizontal FV profile (30-sprint) to a generalized sprint training program. Both groups improved their 30-m sprinting performance, but no significant differences between the groups were observed, and even though this study used a horizontal FV profiling, it corresponds with the results from this study.[12] These results question the horizontal FV profiling, which leads to more uncertainty about this training method. It should be mentioned that improvements in sprinting are more visible at longer sprinting distances,[30] and therefore the 20-m sprint test could potentially not be sufficient to detect possible changes.

Jimenez-Reyes et al.[8] found an increase in jump height (4.1 cm) when training toward an optimal FV profile, and concluded that the improvements could be explained by the FV_{imb} reduction, alone. The average reduction was calculated to be approximately 25 percentage points, and they concluded that an individualized training program addressing the FV_{imb} is more efficient at improving jumping performance than a traditional resistance training program. According to Samozino et al.[6], 25 percentage points could relate to an increase in jump height by ~2% or 0.6 cm, which does not correspond to the findings of Jimenez et al.[8] and casts doubt over their explanation.

Simpson et al.[9] detected that training toward an optimal FV profile showed a two-fold greater increase in the optimal FV profile compared to the general-strength-power group in professional rugby players. This led to greater increases in jumping performance (2.9 cm vs 0.7 cm), peak power, and 3RM squat, and concluded that prescribing FV deficit training is superior to a traditional power training program.[9] The individualized training group decreased their FV_{imb} by 10 percentage points and according to Samozino et al.[6], this affects the jump height by ~1% (0.4 cm), which means that the FV_{imb} reduction cannot explain the increases alone. Additionally, the existence of the theoretical optimal FV profile must be questioned, since power athletes that potentially have maximized their genetic potential have possessed FV_{imb} and shown superior jump heights.[28,29]

Neither Jimenez-Reyes et al.[8], Simpson et al.[9], nor Alvarez et al.[31] detected increases in jump height in the balanced training group, which deviated from multiple strength and power training interventions that are done irrespective of FV profiles.[32–34] A weakness of Alvarez et al.[31] is that the control group did not perform any form of resistance training, and therefore the study does not say anything about how efficient an individualized training program is compared to traditional power training. In addition, when measuring the CMJ and the mechanical outputs an iPhone 7 and MyJump 2 (mobile application) were used, which can be considered as a weakness compared to the force plate.[19,31] The degree of blinding to prevent placebo or nocebo effects has not been described in these studies, and could potentially have affected the results considering that these have shown to exert small to moderate effects on sports performance.[35] All of these limitations could have affected the absolute values and should be taken into consideration. The conclusion that training towards a reduced FV_{imb} for improving jump height can be considered as inaccurate and needs to be more nuanced.

Since this present study did not include a velocity training group, it was in practice compared heavy to combined strength training. Contrarily to this present study, earlier studies have found improvements in different performance variables when performing both heavy and combined strength training.[32–34] Ronnestad et al.[32] compared a combination of heavy and plyometric strength training to heavy strength training alone and a control group. Both of the intervention groups increased different performance variables as 1RM half squat and SJ, but they found that adding plyometrics to the heavy strength training had no significant performance-enhancing effects compared to heavy strength training alone.[32] Since earlier studies have found significant changes with identical training procedures, the completion of the training programs must be questioned.[32–34]

Hacket et al.[33] found that including Olympic weightlifting or/and plyometric training in a power training program can enhance vertical jump to a greater degree than traditional resistance training alone. Additionally, Mangine et al.[34] found that adding ballistic to a heavy strength training program gave superior improvements in 1RM bench press and SJ peak power, compared to heavy strength training alone. Compared to Ronnestad et al.[32] and this present study, these two studies[33,34] were not completed “in-season”. Since both football and handball include a lot of plyometric actions, it can be speculated that adding extra plyometric work during the season is ineffective. The subjects also had a large training volume, and it is possible that the training volume reached the point of diminishing returns, and that a supercompensation and improvements could not occur. This can explain why the balanced training group did not get an additional effect from adding plyometric and ballistic exercises. It can be thought that the players in this present study could have maximized their sprinting performance due to the characteristics of the sports and their training status (elite athletes).[2,36] However, this is highly doubtful since competitive sprinters have improved sprinting performance after a period of resistance training,[37] and similar results were revealed when investigating jumping and sprinting performance in in-season professional footballers.[32] Including a non-training group could have given valuable information and provided an important comparison to the training groups.

6 Main strengths and limitations

The main strengths of this present study were a solid study design, which allowed to examine whether a cause-effect relationship existed between the intervention and the outcome. The sample size (n=40) was sufficient to detect a significant group difference and was representative of in-season elite athletes. Testing protocols were similar to previous research and standardized to a large degree, and the tests were performed with identical measurements and test leaders, which led to increased reliability.

The main weaknesses of this study were that the vertical jump has shown poor reliability in obtaining V_0 and the slope of the FV profile, which could have resulted in force dominant athletes, only. It was not included a non-training control group, which could have provided an important comparison to the training groups. The squat jump depth and the testing outfits were not standardized from pre- to post-test and could have affected the results. Additionally, it existed a photocell problem, that could have led to the athletes missing their best attempt during sprinting.

7 Perspective

This present study included a large sample of elite handball and football athletes. Unfortunately, all of the subjects were categorized as velocity dominant. This led to two training groups only, that can be considered a heavy strength and a balanced strength training group. Neither of the groups changed their FV_{imb}, where training toward or irrespective of the optimal FV profile showed no differences, which questions the SJ-FV profiling.
Multiple confounding factors could have affected the outcomes, but considering the complications with SJ-FV profiling, this study concludes that prescribing training based on an individual optimal FV profile is inefficient and highly questionable.

Instead, developing power and aiming to shift the FV curve to the right should be prioritized. Future research should focus on new forms for individualized training methods to improve both jumping and sprinting performance, but also other important performance variables as well.

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I would like to thank the subjects that participated in this study. Your participation and effort during the training period are highly appreciated. The author declares that he has no conflict of interest.

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PART 3

APPENDICES

APPENDIX 1 Approval by the Norwegian Centre for Research Data

Norsk Kolbjørn Andreas Lindberg

Optimal trening for kraft og hastighet, individualisert trening og motivasjon

Referanse
963169

Status
Vurdert

Åpne Meldeskjema | Vurdering

Skriv melding her. Vær oppmerksom på at meldingen du skriver blir synlig for din institusjon i Meldingsarkivet og alle som får delt tilgang til prosjektet ditt.

Send melding

Sluttvurdering (planlagt)
01.06.2022 02:00

Melding
28.04.2021 10:34

Behandlingen av personopplysninger er vurdert av NSD. Vurderingen er:

Det er vår vurdering at behandlingen vil være i samsvar med personvernlovgivningen, så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet 28.04.2021 med vedlegg, samt i meldingsdialogen mellom innmelder og NSD. Behandlingen kan starte.

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

TYPE OPPLYSNINGER OG VARIGHET
Prosjektet vil behandle alminnelige personopplysninger og særlige kategorier av personopplysninger om helseforhold frem til 01.06.2022

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

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

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

PERSONVERNPRINSIPPER
NSD vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen:

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

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

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

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

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

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

OPPFØLGING AV PROSJEKTET
NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Lykke til med prosjektet!

Kontaktperson hos NSD: Kajsa Amundsen

Melding
28.04.2021 09:18

NSD har begynt på vurderingen av meldeskjemaet, og vi har noen kommentarer før vi kan ferdigstille den.
Når du har oppdatert meldeskjemaet i tråd med kommentarene, trykk «bekreft innsending» på siden Send inn.
Meldingsdialogen kan benyttes til eventuelle spørsmål, svar og avklaringer.

Hei og takk for oppdateringer.
Vurderingen er skrevet ferdig, men før vi kan sende den må dere gjøre to endringer i meldeskjema slik at det samsvarer med informasjonsskrivet:

1) På siden Utvalg 1 ved datakilden under "Grunnlag for å behandle særlige kategorier av personopplysninger" må dere svare "Uttrykkelig samtykke (art. 9 nr. 2 bokstav a)".

2) På siden Varighet under " Skal data med personopplysninger oppbevares utover prosjektperioden?" må dere svare "Nei, data vil bli oppbevart uten personopplysninger (anonymisering)" og her oppgi anonymiseringstiltak.

Trykk deretter Bekreft innsending på siden Send inn.

Melding fra Kolbjørn Andreas Lindberg
23.04.2021 16:23

Hei, takk for tilbakemelding.

1) vi har korrigert dette nå

2) Vi har nå oppdatert ordlyden på punkt 2 fra prosjektbeskrivelsen og lagt det til i informasjonsskrivet så dette blir mer presist og samsvarer begge steder

Mvh Kolbjørn

Melding
20.04.2021 11:12

NSD har begynt på vurderingen av meldeskjemaet, og vi har noen kommentarer før vi kan ferdigstille den.
Når du har oppdatert meldeskjemaet i tråd med kommentarene, trykk «bekreft innsending» på siden Send inn.
Meldingsdialogen kan benyttes til eventuelle spørsmål, svar og avklaringer.

Hei Thomas og Kolbjørn,
Vi har nå gjort en første gjennomgang av meldeskjemaet, og har to kommentarer/spørsmål:

1) I informasjonsskrivet fremgår det at "Prosjektet avsluttes 01.06.2022 og da vil kodelisten destrueres, noe som betyr at innsamlet informasjonen er anonymisert og ingen opplysninger kan spores tilbake til deg". Mens i meldeskjemaet på siden varighet er det huket av for at datamaterialet med personopplysninger skal lagres frem til 01.01.2027. Her må det være samsvar.

2) Under prosjektbeskrivelse fremgår det at prosjektet har to formål "1) Undersøke om individualisert trening basert på kraft-hastighets-tester optimaliserer kraft-hastighets-forholdet, og derigjennom forbedrer prestasjon og motivasjon for å trene. 2) Undersøke effekten av placebo i en styrketreningsintervensjon". Vi kan ikke se at informasjon om det andre formålet fremgår fra informasjonsskrivet. Ber om avklaring.

APPENDIX 2 Application for ethical approval of research project

UiA Universitetet i Agder

Kolbjørn Andreas
Lindberg

Besøksadresse:
Universitetsveien 25
Kristiansand

Ref: [object Object]

Tidspunkt for godkjenning: : 24/05/2021

Søknad om etisk godkjenning av forskningsprosjekt - Optimal trening for kraft og hastighet, individualisert trening og motivasjon

Vi informerer om at din søknad er ferdig behandlet og godkjent.

Kommentar fra godkjenner:

Hilsen
Forskningsetisk komite
Fakultet for helse - og idrettsvitenskap
Universitetet i Agder

UNIVERSITETET I AGDER
POSTBOKS 422 4604 KRISTIANSAND
TELEFON 38 14 10 00
ORG. NR 970 546 200 MVA - post@uia.no -
www.uia.no

FAKTURAADRESSE:
UNIVERSITETET I AGDER,
FAKTURAMOTTAK
POSTBOKS 383 ALNABRU 0614 OSLO

APPENDIX 3 Informed written consent signed by the subjects

Vil du delta i forskningsprosjektet

" Effekten av individualisert styrketrening på styrke og eksplosivitet – En randomisert kontrollert studie"

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke effekten av individualisert styrketrening basert på kraft-hastighetsprofilering hos trente idrettsutøvere. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

I idretter som stiller krav til hurtighet og spenst må utøveren kombinere styrketrening med tunge vekter på ene siden, samt sprint- og spenst-trening med kroppsvekt eller lett motstand på den andre. I mellom disse ytterpunktene har vi olympiske løft og «power-trening» med moderat tunge vekter. Det er en utfordring for mange utøvere å finne balansen mellom disse treningsmetodene, og i lagidretter trener ofte alle utøvere likt, selv om det er store individuelle forskjeller i fysiske styrker og svakheter. Nye studier peker i retning av en mer individualisert styrketrening, der den prioriterte metoden bestemmes av spesielle kraft-hastighets-tester. Eksempelvis bør muligens en utøver som har stor styrke, men lav hastighet, prioritere spenst- og hurtighetstrening framfor tung styrketrening. Flere nylige studier støtter denne hypotesen om at individualisering av styrke- og powertrening er viktig for god/optimal utvikling av power i form av spenst og hurtighet. Fra tidligere forskning vet man også at motivasjon til trening påvirker blant annet kvaliteten på gjennomføringen av økten. Det er derfor stor grunn til å tro at mye forskning hvor man sammenligner treningsopplegg, blir påvirket gjennom forventninger og motivasjon man har til treningsopplegget. Formålet med studien er derfor todelt: 1) Undersøke om individualisert trening basert på kraft-hastighets-tester optimaliserer kraft-hastighets-forholdet, og derigjennom forbedrer prestasjon og motivasjon for å trene. 2) Undersøke effekten av forventninger og motivasjon i en styrketreningsintervensjon. Prosjektet vil være med på å gi oss mer kompetanse når det kommer til treningsplanlegging, og være relevant og interessant for både utøvere og de som jobber med idrettsutøvere.

Mulige fordeler og ulemper ved deltakelse i prosjektet

Fordeler:

- Treningsprogrammene er laget for at du skal oppnå økning i maksimal og eksplosiv styrke, samt muskelvekst i trente muskler.
- Du vil få mer informasjon om hvordan spesifikk trening virker på deg

- Som forsøksperson vil du få å tilegne deg mer kunnskap om din kapasitet og prestasjon relatert til styrke, spenst, hurtighet og power, normalt ikke er tilgjengelig for deg.
- Du vil få oppfølging og veiledning før, etter og gjennom powertrening i 8 uker.

Ulemper:

- Tid må avsettes til gjennomføring av trening og testing.
- Trening og testing kan føre til stølhet og oppfattes som ubehagelig/smertefullt i etterkant.
- Det er en risiko for skader ved både testing og trening, men ikke større enn ved trening du er vant med fra før.
- DXA (måling av muskelmasse) medfører en lav røntgenstrålingsdose, men anses ikke som farlig og tilsvarer dosen en utsettes for under en interkontinental flyreise.

Hvem er ansvarlig for forskningsprosjektet?
Universitetet i Agder (UiA) er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?
Du blir spurt om å delta i prosjektet da du treffer målgruppen som er idrettsutøvere på høyt nivå, og du og/eller din fysiske trener har godkjent at vi kan forhøre oss om mulig deltakelse.

Hva innebærer det for deg å delta?

Dette er et spørsmål til deg som er idrettsutøver om å delta i et forskningsprosjekt der hensikten er å
undersøke effekten av individualisert trening styrke og eksplosivitet. Studien blir gjennomført av forskere Universitet i Agder, Høgskulen på Vestlandet, og Olympiatoppen i Region Vest og Region Øst. Testing og trening vil foregår på de respektive treningssentra og laboratoriene i Kristiansand, Bergen og Fredrikstad.

Hvis du velger å delta i prosjektet, innebærer det at du

- Gjennomfører 2 treningsøkter per uke i 8 uker
- Gjennomfører fysiske tester fordelt på 2 dager før og etter en 8 ukers treningsperiode
    - Testingen vil ta ca. 2 timer per dag

De fysiske testene består i: Svikthopp med 0,20, 40, 60, og 80 kg, 30m sprint, Beinpress og mål av muskelmasse gjennom Dual x ray absorptiometry (DXA).

Styrketreningen vil bestå av tilsvarende identiske treningsprogram som er brukt i tidligere forskning på individualisert trening basert på kraft-hastighetsprofilering. Dette innebærer 2 økter i uken, over totalt 8 uker, med fokus på styrke og eksplosivitet for bein. Utøveren vil kunne også trene egne økter for overkropp dersom dette er ønskelig.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet.

Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
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.

Opplysninger som registreres om deg er:

- Høyde, vekt, fødselsdato
- Styrke, spenst, hurtighet og muskelmasse

Universitetet i Agder er ansvarlig for all informasjon som samles inn i dette prosjektet. Informasjon om deg vil behandles avidentifisert. Det betyr at vi gir deg et forsøkspersonnummer og linker all innsamlet informasjon til dette nummeret. Vi har en kodeliste (ett eksemplar) som kobler navnet ditt til forsøkspersonnummeret. Kodelisten oppbevares i et låsbart skap og det er kun prosjektleder som har tilgang (Thomas Bjørnsen). Prosjektet avsluttes 01.06.2022 og da vil kodelisten destrueres, noe som betyr at innsamlet informasjonen er anonymisert og ingen opplysninger kan spores tilbake til deg.

Hvis du sier ja til å delta i studien, har du rett til å få innsyn i hvilke opplysninger som er registrert om deg. Du har videre rett til å få korrigert eventuelle feil i registrerte opplysninger. Dersom du trekker deg fra studien, kan du kreve å få slettet innsamlede opplysninger/data, med mindre opplysningene allerede er inngått i vitenskapelige publikasjoner. Informasjon som brukes i eventuell vitenskapelig publikasjon vil ikke kunne spores tilbake til deg.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er [01.06.2022]. Alle testresultater vil bli behandlet uten navn og fødselsdato eller andre direkte persongjenkjennende opplysninger. En kode knytter deg til dine opplysninger og testresultater gjennom en navneliste. Det er kun prosjektleder som har adgang til navnelisten og som kan finne tilbake til deg. Listen destrueres så snart studien er gjennomført. Det vil ikke være mulig å identifisere deg i resultatene av studien når disse publiseres.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
- å få rettet personopplysninger om deg,
- å få slettet personopplysninger om deg, og
- å sende klage til 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 Universitetet i Agder har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

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

- Kolbjørn Lindberg, doktorgradsstipendiat ved Universitetet i Agder (kolbjorn.a.lindberg@uia.no, +47 908 70 067)
- Thomas Bjørnsen, prosjektleder og førsteamanuensis ved Universitetet i Agder (thomas.bjornsen@uia.no, +47 986 19 299).
- Paul Solberg, faglig leder Olympiatoppen Øst (paul.solberg@olympiatoppen.no, tlf: 99094092).
- Robert Brankovic, Universitetslektor ved Høgskulen på Vestlandet (r0bertme@gmail.com, +47 977 51 984)
- Morten Kristoffersen, førsteamanuensis ved Høgskulen på Vestlandet (Morten.Kristoffersen@hvl.no, +47 930 92 244)
- Vårt personvernombud: Ina Danielsen (ina.danielsen@uia.no, +47 452 54 401)

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:

- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Med vennlig hilsen

Kolbjørn Lindberg og prosjektmedarbeidere

(stipendiat, forsker og veileder)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet ” ***Effekten av individualisert styrketrening på styrke og eksplosivitet*** ”, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ☐ å delta i prosjektet ” ***Effekten av individualisert styrketrening på styrke og eksplosivitet*** ”

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

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(Signert av prosjektdeltaker, dato)