Upper- & lower body strength and its correlation to performance in swimming

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Abstract

**Background:** To learn how to swim with proper technique takes fairly large amount of time and practice to learn and an elite swimmer spends 6-7 days training for improving aerobic capacity, anaerobic capacity and strength training for energy saving technique. Freestyle is the fastest swimming style and is performed in many different distances, 50m is classified as a sprint and the 400m as a middle-distance. The research is inconclusive if there is a correlation in the lower body and the time in 50m and 400m and mostly in the middle distance which gives this study the importance reducing these uncertainties.

**Aim:** The aim of this study was to determine the strength of the correlation between the upper- and lower body muscle strength with time in 50m and 400m freestyle and to analyze which of the variables of height, sex, upper- and lower body strength contribute to velocity in sprint and middle distance in competitive swimmers.

**Method:** A total of 14 participants (3 men and 11 women) participated in the study. The participants were tested at three occasions. The first was to determine their three-repetition maximum (3RM) in the squat and lat-pulldown. The second occasion was the collection the time in 50m freestyle and the third was to collect the time in 400m freestyle. Relative strength (kg/kg BW; %) and absolute strength (kg) in 1RM was calculated and correlated with the time in 50m and 400m freestyle. Analysis was done to see which variables of height, sex, relative strength in the squat and lat-pulldown contribute the most to the time in freestyle.

**Result:** The result show that there was a high correlation between the absolute strength in the squat and the time in 50m (r=-0.769) a moderate correlation in the absolute strength in lat-pulldown and the 50m freestyle sprint (r=-0.513). There was also a moderate correlation for the relative strength in the lat-pulldown and 50m freestyle (r=-0.599). The 400m correlate with the relative strength in both lat-pulldown(r=-0.563) and the squat (r=-0.555). The lat-pulldown contributed most to the time in 50m freestyle as well as the male sex.

**Conclusions:** The absolute strength in the squat had a high correlation to the time in 50m freestyle swim. The 400m there was a moderate correlation to the relative strength in the squat and lat-pulldown showing that for the overall performance in middle-distance the relative strength has the advantage over absolute strength. The relative and absolute strength in upper body correlated to both 50m and 400m freestyle and could therefore strengthen the importance of upper body strength in sprint and middle distance as previous researchers has stated. The upper body strength is the best predictor of time in 50m.

**Keywords:** Swimming, Freestyle Swim, Strength, Squat, Lat-pulldown, Velocity, 50m, 400m
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1.0 Background

To learn how to swim with proper technique takes large amount of time and practice. Most people learn how to swim at a young age as it is an important skill to master for safety and exercise purposes. To be able to swim as a recreational or as an elite swimmer requires a good aerobic and anaerobic capacity (Barden & Kell, 2009). In competitive swimming, on an elite level, there are four different styles (from slowest to fastest); breaststroke, backstroke, butterfly and crawl (i.e., freestyle). These are commonly performed in a 25m or 50m pool but also in open water for longer distances. A competitive swimmer spends approximately 6-7 days a week training and completes between 10.000-14.000 m of swimming during each practice (Heinlein & Cosgarea, 2010)

In a competition, the swimmer starts from a starting block, at the signal the swimmer dives into the water, uses the legs for underwater kicks before reaching the surface and performs the chosen style. When doing distances in a 25meter pool the swimmer does a turn at the end of the pool which is executed differently for each swimming style (Heinlein & Cosgarea, 2010). For the fastest swim style, the freestyle, the turn is called a “flip turn” that resembles a somersault. The freestyle swim contains both kicks with the legs and push and pull (drag) movements with the arms, which is performed mainly in the glenohumeral joint (Heinlein & Cosgarea, 2010). The arm movement in the freestyle swim can be divided into three general phases, which include both pushing and pulling of the arms. The first phase is the glide phase and occurs when the hand touches the surface of the water with the arm held in front and lateral of the head, m. deltoïds performs most of the work in this phase. The second phase is the pull phase and this occurs under water by pulling the water backwards making the body move forward primarily using the muscles m. pectoralis major and latissimus dorsi. The third phase is the recovery phase with no water resistance, which is the passive over water movement before the glide phase starts again. There is a lot of muscle activity working to produce force in the upper body but also several muscles stabilizing the joints (Barbosa, Marinho, Mário, & António, 2011; Heinlein & Cosgarea, 2010). The legs and the core are also essential for swimmers and the legs work simultaneously with the arms with both flexion and extension in the art. coxae. These are called the kicks and use the muscles around the hip area(Heinlein & Cosgarea, 2010). The core muscles are essential for swimmers because they use the whole body to transfer the forces. If there is lack of core stability the muscles can’t transfer the force from the hands to the legs (Weston et al., 2015; Crowley, Harrison & Lyons,
All movement occurring in the joints require neuromuscular coordination and muscle contraction, to be able to move forward as efficient and fast as possible in the water.

1.1 Physiology

1.1.1 The Muscle anatomy & Sliding filament Model

All parts of the body contain cells and so does the skeletal muscles, whose cells are called muscle fibers and the size and quantity of these fibers vary for each muscle. Within each muscle fiber there are myofibrils, which is the smallest functional part of the muscle fibers and these are sectioned up by several sarcomeres. A sarcomere is bounded by z-lines at the ends and when the muscle contracts the z-lines gets closer to the center of the sarcomere through the interaction between the actin and myosin filaments, called the sliding filament model (McArdle, Katch, & Katch, 2015). Before the muscle can contract there must be a signal from the brain to the muscle which activates the right amount of muscle fibers. These motor neurons connects to the muscle fibers and forms neuromuscular junction where the neurotransmitter is acetylcholine is released. When the acetylcholine receptors in the muscle fiber are activated there is a depolarization, which causes the sarcoplasmic reticulum to release calcium ions (Ca$^{2+}$). Ca$^{2+}$ binds to troponin-tropomyosin on the actin, which initiates a conformational change of the tropomyosin and myosin can now attach to actin and a cross bridge is formed. ATP, the muscles energy is broken down to adenosine diphosphate (ADP) and inorganic phosphate in the muscle action. The myosin-actin interaction pulls the z-lines closer to the middle of the sarcomere. A new ATP molecule makes the myosin head to detach from the actin and in the presence of Ca$^{2+}$ the cross-bridge cycles continue, or when Ca$^{2+}$ is recycled into the sarcoplasmic reticulum, the muscle can relax (McArdle, Katch & Katch, 2015). For swimmers the wish to move faster are desired, therefore an increase in force production are necessary in the muscles.

1.1.2 Strength

Force is produced by the muscles and to increase the force production power and strength are important. Strength is defined as the maximal force that a muscle or muscle group can generate at a certain velocity (Baechle & Earle, 2008; McArdle, Katch & Katch, 2015). Power is the ability to generate force at as high velocity as possible. In the human body there are many factors contributing to strength, the cross-sectional area of the muscle, fiber type, muscle length, angle of the joint, body size, neural control and muscle contraction velocity and these work simultaneously (McArdle, Katch & Katch, 2015). When an athlete becomes
stronger more motor units are recruited which stimulate more muscle fibers. The neurons fire in a faster rate and a higher frequency which increase the force and the neuromuscular function of the muscles (McArdle, Katch & Katch, 2015). This way the athlete can activate more muscle fibers and lift more weight. Skeletal muscle fibers have different characteristics and are in humans often divided into three types (Type I, Type IIa and Type IIx) (McArdle, Katch & Katch, 2015). Different muscles have different combination of the three fiber types and the force production and use of TP differ between the fiber types. Combination of the three fiber types and the production and use of ATP differ between the fibers. The Type I fibers are generally more fatigue resistant and used in aerobic conditions when oxygen is available through more mitochondrias. The Type II (Type IIa and Type IIx) fibers have a fast force production and are used in anaerobic work when oxygen is not present and rely on the use of glycolysis system (McArdle, Katch & Katch, 2015). The fast twitch fibers could be three to five times faster in tension development compared to the slow twitch (Type I). When performing heavy strength training there will be damage to the muscle and after the training session the muscle need to recover to gain the strength. Strength training and strength are thought to come from two factors; the metabolic stress through the energy depletion of the activated muscle fibers, and the mechanical through the activated muscles tension against an external force (Mangine et al., 2018).

To test if an athlete becomes stronger a strength test is appropriate (Tanner & Gore, 2013) which can be done in several exercises with the purpose to see the strength development after for example a training period. When testing the strength of an athlete the 1 repetition maximum (1RM) is considered the gold standard (Seo et al., 2012). The relative strength is another strength assessment, this is done by dividing the absolute strength to for example the body weight or the fat-free mass. This makes it possible to compare heterogeneous groups, different ages, men and women, etcetera (McArdle, Katch & Katch, 2015). To be able to produce the force required in the exercise there is a need for energy in the muscle. There are three different systems that produce energy with and without oxygen available.

1.1.3 Energy utilization
When looking into the metabolism of the muscles there are three systems that produce ATP which is the muscles energy, which makes it possible for the muscle to contract. The first two systems work without oxygen available, the phosphagen and glycolytic system and when oxygen becomes available the oxidative phosphorylation system is used including the citric
acid cycle and electron transport chain in the mitochondria (McArdle, Katch & Katch, 2015). The phosphagen system is primarily used during a strength test, lasting only a few seconds, this system performs the breakdown of creatine phosphate. All of the systems work simultaneously, in swimming the primary energy system change from phosphagen in shorter distances to oxidative phosphorylation in the longer distances, there is also a change in demands of the joints and muscles when switching from shorter to longer distances (Baechle & Earle, 2008; McArdle, Katch & Katch, 2015).

1.1.4 Swim performance and sex differences

Some anthropometrics have been shown to correlate with increased performance in swimming, for example, height, hand and foot size have high correlations with increased performance (Helmuth, 1980; Lätt et al., 2009). Thus, being taller can be an advantage in swimming, which gives an advantage to men over women where male swimmers generally have longer stroke length and faster sprint times compared to women (Hawley, Williams, Vickovic, & Handcock, 1992). Besides being taller and have larger hands and feet (Morais et al., 2013) men usually have more upper body muscle mass which is related to more strength (Nóbrega, Ugrinowitsch, Pintanel, Barcelos, & Libardi, 2018). Men have different fat distribution and lower fat mass compared to women, who generally have more body fat than men and fat floats better than muscle mass in water. This gives women a better water alignment than men and women uses around 30% less energy with a better streamline position (McArdle, Katch & Katch, 2015). Womens fat is distributed more around the hip giving further streamline enhancement (Shi, Seeley & Clegg, 2009). Women also have their center of buoyancy closer to their center of mass than men, which could lead to a more horizontally position in the water (McLean & Hinrichs, 1998).

Women have less upper body muscle mass relative to the total body mass compared to men (Gallagher & Heymsfield, 1998; Janssen et al., 2014) and they generate a lower absolute and relative power and strength than men (Hubal et al., 2005; Buśko & Gajewski, 2011). To be aware of sex differences is important in every sport and situation but in swimming technique based on men’s and women’s unique anthropometrics could further enhance swim performance in both sexes.
1.2 Technique in swimming

The technical aspect of the freestyle swim involves the two stroke parameters stroke length and stroke rate. The relationship between stroke rate and length is important for increased velocity and thus increased swim performance (Barden & Kell, 2009; S Girold, Calmels, Maurin, Milhau, & Chatard, 2006; Matthews, Green, Matthews, & Swanwick, 2017). Stroke rate refers to strokes per minute, which is an important factor for swimming velocity and performance (Mooney et al., 2017). Stroke length is described as how long each stroke is (Mooney et al., 2017). A strong correlation has been shown between the time in 50m freestyle and the stroke length for men ($r=0.93$) and women ($r=0.82$) implicating that stroke length is important for swimming velocity and in sprint distances (Hawley et al., 1992). Previous research showed that when a swimmer gets fatigued the stroke rate decreases along with the stroke length and therefore the velocity. More experienced swimmers tend to have a smaller decline in length of the stroke (Figueiredo, Seifert, Vilas-Boas, & Fernandes, 2012; Matthews et al., 2017). Moreover, the external rotation of the art. humeri is reduced when fatigued which could be the reason behind a lower stroke length and rate (Matthews et al., 2017).

When the swimmer reaches above the lactate threshold (where lactate accumulate faster than removed) the stroke rate tends to decrease (Dekerle, Sidney, Hespel, & Pelayo, 2002).

One of the determining factors for a high sprint velocity in swimming (e.g. 50m freestyle) is the start (Bishop et al., 2013; Morais et al., 2013) which can contribute to 30 % faster sprint times (Cossor & Mason, 2001). Furthermore, an optimally performed flip turn in the 25m pool can further lead to additional time reduction (Bishop et al., 2013). Both upper- and lower body muscle strength are important factors for both the start and the turn (Bishop et al., 2013; Fig, 2010; West, Owen, Cunningham, Cook, & Kilduff, 2011) and overall strength has been shown to be more important than technique in swim sprints i.e., 25m or 50m (Morais et al., 2013). A good overall strength is also needed to improve the streamline position, which is the body’s alignment in the water which makes the body move quicker and easier in the water (Barbosa et al., 2011).

1.3 Strength-training for swimmers

Strength training is performed for the purpose to increase or maintain muscle strength. Traditional strength training using free weights increased performance in freestyle by over 2 %, which is around 5 sec reduction of swim time (Girold et al., 2012) and in the 400m the time was reduced by 3.74 sec (González-Boto, Salguero, Tuero, González-Gallego, &
Traditional strength training for swimmers is performed in a gym using exercises that resemble the movements in swimming such as the lat-pulldowns, triceps extensions, bench-press, squats, dips and pull-ups. The traditional high force strength training gives a better recruitment of the faster type II muscle fibers and a lower neurological fatigue compared to a high volume low intensity training (Crowley, Harrison & Lyons, 2017). If swimmers do not have access to a gym, assisted weight training is another way to improve muscle strength with the use of the body weight only. A study found that after an intervention where swimmers trained either with free weight or with weight assisted training, both groups improved in performance of freestyle swimming (Trappe & Pearson, 1994). The conclusion was that it may be easier for the swimmer to perform the weight assisted training as pull-ups and dips if they do not have access to a gym (Trappe & Pearson, 1994).

Resistance training in swimmers, using free weights and machines, led to strength improvements and swim performance (Amaro, Marinho, Marques, Batalha, & Morouço, 2016; Garrido et al., 2010). By implementing strength training the time could be reduced by 2% and 4% in 50m and 25m, respectively (Morouço et al., 2011). This could also enhance the stroke length and by using tethered swimming the stroke rate increased as well (Barden and Kell, 2009; Crowley, Harrison & Lyons, 2017; Matthews et al., 2017). In another study it was shown that the 400m freestyle improved as well by implementing heavy strength training (González-Boto et al., 2008) and with the use of isometric training further improvements could be achieved especially in the elbow flexion and shoulder extension muscles and swim performance (Gola et al., 2014).

Swimmers require a good upper body strength for an increase in velocity (Kim et al., 2016) since studies have shown that upper body muscles contributes to 75-90% to the swim velocity, whereas 10-25% comes from the lower body (Gola et al., 2014; Morris et al., 2016). The pull-up is often used when testing the upper body strength of the back muscles in swimmers (Coyne et al., 2015). The lat-pulldown is a similar exercise to the pull-up, except that the athlete pulls the bar towards the chest instead of pulling the body weight up. The movement in these exercises are similar to the arm movement in the freestyle swimming. The use of strength training protocols mainly using the upper body has shown to improve the time of swim sprints of 25m and 50m (Girold et al., 2007; Gola et al., 2014; Kim et al., 2016; Morris et al., 2016). Swimmers spend a fairly large amount of time in the pool and on strength training, and what guidelines to follow to enhance the swim performance by strength training...
is unclear. With previous research showing inconclusive result mainly in the 400m freestyle, gives this study the opportunity to lessen these uncertainties.

A correlation has been observed between the upper and lower body in power output and performance in 50m ($r=\frac{3}{3}$) and the peak sustained workload in 400m ($r=0.70$) (Hawley et al., 1992). A hypothesis has been put forth that strength training could decrease a swimmer’s range of motion and impair performance mainly in the upper body (Newton, Jones, Kraemer, & Wardle, 2002). The underlying theory is that strength training can lead to muscle hypertrophy and this could lead to increased form drag might impair the performance (Newton et al., 2002). In contrast, contradictory results has shown that strength training will indeed improve the swim performance (González-Boto et al., 2008; Girold et al., 2012; Gola et al., 2014; Crowley, Harrison & Lyons, 2017). This could lead to reduction in injury risk in the shoulder (Matthews et al., 2017). The most prevalent outcome measure in swimming research is the power whereas the knowledge on strength is unclear, in particular, in the lower body.

### 1.4 Aim

The aim of this study was to determine the strength of the correlation between the upper- and lower body muscle strength with time in 50m and 400m freestyle and to analyze which of the variables height, sex, upper- and lower body strength contribute more to velocity in sprint and middle distance in competitive swimmers.

#### 1.4.1 Research questions

The research questions for this study were:

- How strong is the correlation between muscle strength in the upper body in the lat-pulldown and lower body in the squat with the time of 50meter freestyle swimming?

- How strong is the correlation between muscle strength in the upper body in the lat-pulldown and lower body in the squat with the time of 400meter freestyle swimming?

- To what degree does height, relative strength in the lat-pulldown, relative strength in the squat, height and sex contribute to the velocity in 50m sprint and 400m middle distances in freestyle in competitive swimmers?
2.0 Methods

2.1 Study design

This study was a cross sectional, correlation study, conducted at three test occasions. The first occasion was performed in a local gym to determine the participants 3RM in the squat and the lat-pulldown. At the second occasion the swim time in 50m freestyle was collected and at the third occasion the time in 400m freestyle. During all three occasions a supervisor was present, and the participants were monitored carefully. Before the tests the participants got a written informed consent (appendix 1), which also was signed. Verbal encouragement was used in both the strength tests and swimming tests to maximize the participants performance (West et al., 2011).

2.2 Participants

A total of 16 competitive swimmers participated in the study from the start. There were two drop outs who did not perform all tests and therefore the study included 14 participants for the 50m swim. Two more participants did not do the 400m swim, which resulted in 12 participants who finished all the tests. The participants were included if their age was between 15-25 years old. All of the participants attended voluntarily and were given a written and oral presentation of the study before the start. The inclusion criteria were to have a minimum of one year of competing in swimming and have been present at a competition within the last year. They needed to be injury free at the test occasions and six months before and were excluded if they had had an injury to the upper- and/or lower extremities in the last six months that had required medical attention including physiotherapy. Before participation, the participants were told to refrain from high intensity exercise two days prior to testing at all the three occasions. Two hours before testing they were told to not eat a larger meal or consume nicotine, alcohol or caffeine. The swimmer’s coaches were informed about the testing and could adapt the training the days prior to testing. All of the participants had gym experience to some extent.

2.3 Procedure

Before the tests started the participants age, weight and height were collected and they filled out a questionnaire (appendix 2), which involved questions regarding total hours spent training, hours of strength training, their favorite swim style and distance. If they did not know their weight, they used the local gym weight scale. Their previous times in the 50m and
400m freestyle came from Octoopen (a webpage and database which contains every swimmers times and score) and were used for comparing if they performed at or near their best. The swimming tests were done in a 25m swimming pool with a temperature around 28°C and an air temperature around 29 °C and were the same place as their regular training sessions.

2.3.1 Strength measurement
The strength test was done in the local gym where the participants performs their own strength training. The 3RM in the squat was performed first followed by the 3RM in the lat-pulldown. After completion of the 3RM the estimated 1RM was calculated based on the 3RM according to guidelines (Baechle & Earle., 2008 p.397-398). Three repetitions represent 93% of the 1RM in any given exercise. The absolute (kg) and relative (kg/kg BW; %) strength was used for analysis in both the lat-pulldown and squat. The 1RM in the squat has shown to have an intraclass correlation (ICC) of 0.97 (Tanner & Gore, 2013).

2.3.1.1 Squat
The back squat followed the National Strength and Conditioning Association (NSCA) guidelines. The squat was performed in two phases, the first was the eccentric phase, which started in a straight up position with the bar placed behind the head on the m. trapezius. The movement began by a flexion in the hip and knee joint. The squat proceeds down to when femur was parallel to the floor or lower. The concentric phase began when the athlete pushes back up again with an extension in the hip and knee joint to an upright position (Baechle & Earle, 2008). The squat was approved by the test leader if the thigh was parallel to the floor or lower.

The tests started off with a warm-up on a bicycle for 10 minutes followed by 10 repetitions in the squat with a 20kg barbell. Thereafter the participants did five repetitions in the squat on a weight they knew they could handle followed by two minutes rest. After the five repetitions, three repetitions followed with increased weight and three minutes rest before the actual test started. For the 3RM test the participants chose a weight they know from previous experience that they can handle and then increased the weight by 10-20% until they couldn’t perform the squat without proper form. If the participants failed to perform the squat, a 5-10% reduction in weight was taken off. All of the tests were done with a three min rest between the sets, to ensure that the participants recovered properly (Baechle & Earle, 2008). For safety the safety
racks were placed in the squat rack close to the bottom position in the squat, and the test leader acted as a spotter to help in case the participant fail to perform the lift. There was always one spotter present, but for some participants two spotters were needed. If the participant didn’t manage to perform the squat with a proper form the test leader interrupted the test. There was no use of equipment such as; weight lifting shoes, belts or knee support.

The 1RM test is widely used as a measurement for strength and is considered to be the gold standard for several exercises including the squat and lat-pulldown. It has been shown to have excellent reliability (ICC>0.91) for both men and women (Seo et al., 2012). In this study, the 3RM were used as the test method and the 3RM unilateral squat is shown to be a reliable measurement for strength in both untrained and trained individuals. The men and women had excellent intraclass correlation coefficient with ICC=0.97 and ICC=0.94, respectively (McCurdy, Langford, Cline, Doscher, & Hoff, 2004). The more repetitions an athlete performs the less precise the prediction of their 1RM is (Reynolds, Gordon & Robergs, 2006).

2.3.1.2 Lat-pulldowns
When performing the lat-pulldown the participant sat down with the knees in 90° and the participants grasped the bar shoulder width apart, with a pronated grip. Shoulder width was measured from acromion to acromion. A proper form was considered a straight up position in the back and the bar pulled down in front of the head and under the chin (Halet, Mayhew, Murphy, & Fanthorpe, 2009). The bar on the lat-pulldown machine was straight and the grip width was marked with tape, so the same width was used at all the 3-RM attempt, no extra equipment was allowed.

The 3RM in the lat-pulldown followed the same guidelines as for the squat and was performed after the squat. The warm-up was similar to the squat and the participant did the 10 repetitions and lowered the amount of repetitions as the weight increases. The weight was increased until the participant could not manage more than three repetitions with a proper form. The 3RM followed the guidelines for the lat-pulldown by Thomas et al. (2015). If the weight plates on the lat-pulldown machine had too large increase, external weight plates were used to get the desired weight showed in figure 1. The 1RM in lat-pulldown test-retest was found reliable with a ICC of 0.91 (Hollander et al., 2007).
2.3.2 Swimming

After the strength tests the participants performed the swim tests, approximately one week after. They started with a 1000m warm-up, which include the different parts of the freestyle swimming (kicks, push and pull movement of the arm). This was done with low to moderate intensity. The time collection was performed as in a competition, they started at the starting block with their usual starting style and swam the 50m. After this they recovered for 10 minutes and then they did the 50m test again in the same fashion. The participants did this on their normal training and when the 50m test was performed two or three participants started simultaneously to more closely simulate a competition (Gola et al., 2014).

For the third and last test occasion the 400m test was conducted with the same standard warm-up. This test was only collected one time. Both the 50m and the 400m time was collected by using a stopwatch. The stopwatch is a commonly used tool to assess the time of the swimmers and used by the coaches. The stopwatch is shown to be valid and reliable when tested on healthy individuals and the sprint performance was measured with both the stopwatch and the Speedtrap II, which is an infrared timing gate. The reliability showed that there was no difference between the stopwatch and the gates with an excellent ICC value of 0.98. There was a slight difference between the stopwatch and the gates and the stopwatch
showed slightly faster times (0.04 to 0.05 seconds) (Hetzler, Stickley, Lundquist, & Kimura, 2008).

2.4 Ethical and social considerations

2.4.1 Ethical
All participants in this study were contacted in advance and received information about the study. The participation was optional which was also clarified both in person and in text (appendix 1). The participants were informed that they could drop out of the study at any time without the need to provide an explanation. This study followed the ethical principles required when performing studies on humans (World Medical Association, 2013). These principles are mainly the respect, dignity, integrity, confidentiality, privacy, health and no harm to any of the participants. The purpose of the study must not be preceded by the health of the persons concerned (World Medical Association, 2013).

All participants received a written consent (appendix 1) and an oral presentation about the aim and purpose of the study. The participants got information of the potential risks (the amount of stress in the squat), and benefits (knowing their 1RM for training optimization and the 50m and 400m freestyle times) of this study. Opportunities was given to ask questions regarding the participation in the study. As their participation was optional, they could cancel their participation at any time without losing contact with the test leader or the result of the study. No unauthorized person had access to the result of the study or any of the data collected and the study followed the Personal Data Act (1998:204). All the data collected was stored on a USB, which was kept by the test leader.

2.4.2 Social considerations
The present study has the potential to provide the society in general and the world of swimmers in particular information regarding the impact of lower and/or upper body strength have on 50m and/or 400m freestyle swimming. It could provide knowledge to coaches and swimmers about the potential benefits of resistance training and how it affects the swimmer’s performance. There is some inconsistency and misconceptions that the strength training could decrease the range of motion and impair the swimmer’s performance. This information is not only for the elite swimmer but also for the recreational swimmers to give them more knowledge that can help improve their swimming performance. It will also give the
information regarding if the relative and absolute strength is of more importance to swimmers.

General aerobic training, including swimming, is a good way to improve cardiovascular endurance and has been shown to reduce body weight, and the risk of several diseases including cardiovascular disease (Cox, Burke, Beilin, & Puddey, 2010) and improve sleep quality in older people with insomnia (Reid et al., 2010) and even the psychological symptoms of dementia (Neville, Henwood, Beattie, & Fielding, 2013). Among older women the body weight and fat distribution was improved as well as the insulin sensitivity and in the long term the lipids profile improved (Cox et al., 2010). Water based activities reduced the cholesterol and low-density lipoprotein cholesterol. Active women had lower fasting glucose and insulin and the responses to these (Cox et al., 2010). Osteoarthritis is a common disorder among older people and regular swimming reduced the joint pain and improved the muscle strength as there was reduction in muscle stiffness (Alkatan et al., 2016). When inactive women started the low-volume high-intensity swim training the insulin and glucose in the plasma was lowered, which shows improvements in insulin sensitivity (Connolly et al., 2016). Swimming is safe to execute for pregnant women (Juhl, Kogevinas, Andersen, Andersen, & Olsen, 2010). This highlights the health benefits and importance of not only aerobic but also strength training for swimmers at all levels.

2.5 Statistical analysis

The statistical analysis was done in SPSS (IBM SPSS Statistics, Version 24) and all data was presented as mean ± standard deviation (SD). To test if the data was normally distributed the Shapiro-Wilks test was used. This showed that all of the data was normally distributed except the lat-pulldown in absolute strength. To test how strong the correlation was between the estimated 1RM in lat-pulldown and the velocity in 50m and 400m freestyle the Spearman's correlation analysis was done. To test how strong the correlation was between the estimated 1RM in the squat and the velocity in 50m and 400m freestyle the Pearson-correlation analysis was done and also for the relative strength. The significance level was set at p<0.05. The correlation values were set at: 0.0 – 0.30 = no correlation, 0.30-0.50 = low correlation, 0.5 – 0.7 = moderate correlation, 0.7-0.9 = high correlation and 0.90-1.0 very high correlation (Mukaka, 2012). Multiple regression analysis was done to see if upper or lower body relative strength, height and sex contribute to time in 50m and 400m freestyle. The 50m and 400m acted as the dependent variable (time expressed in seconds) and the relative strength in upper,
lower body, height and sex as the independent variables. The $r^2$ value showed how much the dependent variable is explained by the independent variable and the $\beta$-estimate value showed how much of a change there is and in what direction.

### 3.0 Results

The women’s characteristics were; age 15.8 ± 0.6 years, weight of; 63.1 ± 9.0 kg and height of; 171.6 ± 7.3 cm. The men characteristics were; age 18.3 ± 3.2 years, weight of; 73.7 ± 2.1 kg and height of; 182 ± 7.2 cm (table 1).

Table 1. Characteristics of the men and women in mean ± SD and their descriptive data both separately and together.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Women(n=11)</th>
<th>Men(n=3)</th>
<th>All (n=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Descriptive data</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>15.8 ± 0.6</td>
<td>18.3 ± 3.2</td>
<td>16.4 ± 1.7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>63.1 ± 9.0</td>
<td>73.7 ± 2.1</td>
<td>65.4 ± 9.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>171.6 ± 7.3</td>
<td>182.0 ± 7.2</td>
<td>173.8 ± 8.3</td>
</tr>
<tr>
<td><strong>Training parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength training (h/week)</td>
<td>2.5 ± 0.6</td>
<td>2.8 ± 0.6</td>
<td>2.5 ± 0.6</td>
</tr>
<tr>
<td>Training sessions (times/week)</td>
<td>7.6 ± 1.4</td>
<td>7.3 ± 2.5</td>
<td>7.5 ± 1.6</td>
</tr>
<tr>
<td>Swimming practice (h/week)</td>
<td>10.6 ± 1.2</td>
<td>8.5 ± 0.5</td>
<td>10.2 ± 1.4</td>
</tr>
<tr>
<td><strong>Strength tests</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lat-pulldown (kg)</td>
<td>56.8 ± 6.4</td>
<td>90.5 ± 16.0</td>
<td>64.0 ± 16.6</td>
</tr>
<tr>
<td>Lat-pulldown (kg/kg BW; %)</td>
<td>90.7 ± 7.9</td>
<td>122.7 ± 18.5</td>
<td>97.6 ± 16.9</td>
</tr>
<tr>
<td>Squat (kg)</td>
<td>68.5 ± 11.15</td>
<td>93.2 ± 14.8</td>
<td>73.8 ± 15.5</td>
</tr>
<tr>
<td>Squat (kg/kg BW; %)</td>
<td>109.1 ± 14.6</td>
<td>126.3 ± 16.2</td>
<td>112.8 ± 16.1</td>
</tr>
<tr>
<td><strong>Swim tests</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time 50m (sec)</td>
<td>29.9 ± 0.9</td>
<td>27.5 ± 0.8</td>
<td>29.4 ± 1.4</td>
</tr>
<tr>
<td>Time 400m (sec) (n=10)</td>
<td>308.5 ± 12.0</td>
<td>295.8 ± 0.6</td>
<td>306.4 ± 12.3</td>
</tr>
<tr>
<td>Time 400m (sec) (n=2)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BW=Body weight

The participants in the study were asked to list their favorite style of swimming and four of them chose freestyle, three backstroke, two breaststroke and seven butterfly. The participants preferred sprint as a distance and especially 50m (n=6). No one that had a favorite distance over 200m.
3.1 50m freestyle

3.1.1 50m and lat-pulldown

The time in 50m freestyle swim were 29.4 ± 1.4sec. The absolute strength in the upper body during the lat-pulldown were 64.0 ± 16.6kg. The correlation between the absolute strength in the lat-pulldown and the 50m showed a moderate negative correlation (r=-0.513, p=0.061). The more weight pulled down in the lat-pulldown the faster time in the 50m freestyle swim where 26% of the variation in 50m could be explained by upper-body strength in lat-pulldown (table 2, figure 2A).

Table 2. Correlation coefficients and p-values for the 50m and 400m freestyle and the absolute(kg) and relative strength(kg/kg BW) in the squat and lat-pulldown.

<table>
<thead>
<tr>
<th></th>
<th>Squat A (Kg)</th>
<th>Squat R (Kg/kg BW)</th>
<th>Lat-pulldown A (Kg)</th>
<th>Lat-pulldown R (Kg/kg BW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50m</td>
<td>-0.769</td>
<td>-0.475</td>
<td>-0.513</td>
<td>-0.599</td>
</tr>
<tr>
<td>p-value</td>
<td>0.001</td>
<td>0.086</td>
<td>0.061</td>
<td>0.024</td>
</tr>
<tr>
<td>400m</td>
<td>-0.478</td>
<td>-0.555</td>
<td>-0.239</td>
<td>-0.563</td>
</tr>
<tr>
<td>p-value</td>
<td>0.116</td>
<td>0.061</td>
<td>0.455</td>
<td>0.057</td>
</tr>
</tbody>
</table>

A = Absolute strength; R = Relative Strength; BW = Body weight

In the relative strength the lat pulldown were 97.6 ± 16.9%. The correlation between the lat-pulldown and the 50m showed a significant moderate negative correlation (r=-0.599,
p=0.024). The more percent lifted of the body weight the better times in 50m freestyle swim with 36% of the variation in time of 50m be explained by changes in the lat-pulldown (table 2, figure 2B).

### 3.1.2 50m and squat
The time in the 50m freestyle swim were 29.4 ± 1.4 sec. The absolute strength in the squat were 73.8 ± 15.5 kg and the correlation between the absolute strength in the squat and the 50m freestyle showed a significant high negative correlation (r= -0.769, p=0.001). The more weight lifted in the squat the faster time in the 50m freestyle swim where 59% of the variation in time of 50m could be explained by changes in the squat (figure 3, table 2).

![Figure 3. The correlation between the absolute weight in the squat and the time in 50m freestyle (r=-0.769)](image)

The relative strength in the squat were 112.8 ± 16.1%. The correlation between the relative strength in the squat and the 50m showed a low negative correlation (r= -0.475, p=0.086). There were no significant results that showed that the more percent lifted of the body weight correlated with faster time in the 50m freestyle swim (table 2).

### 3.2 400m freestyle
Two of the participants did not perform the 400m so the data is based on 12 participants.
3.2.1 400m and lat-pulldown

The time in 400m were 306.4 ± 12.3sec. The absolute strength in the lat-pulldown were 64.0 ± 16.6kg and the correlation between the absolute strength in lat-pulldown and the 400m showed a low negative correlation (r= -0.239, p=0.455). There were no significant results showing that the more weight lifted in the lat-pulldown correlated to faster time in the 400m freestyle swim (table 2).

The relative strength in the lat-pulldown were 97.6 ± 16.9% and the correlation between the lat-pulldown and the 400m showed a moderate negative correlation (r= -0.563, p=0.057). The results showed that the relative weight lifted in the lat-pulldown correlated with faster time in the 400m freestyle swim were 32% of the variation in time of 400m could be explained by changes in the lat-pulldown (figure 4, table 2).

![Figure 4. The correlation between the relative weight in the lat-pulldown and the time in 400m freestyle (r=-0.563)](image)

3.2.2 400m and squat

The time in 400m were 306.4 ± 12.3sec. The absolute strength in the lower body in the squat were 73.8 ± 15.5kg and the correlation between the squat and the 400m showed a low negative correlation (r= -0.478, p=0.116). There were no significant results that showed that the more weight lifted in the squat correlated to faster time in the 400m freestyle swim (table 2).

The relative strength in the squat were 112.8 ± 16.1% and the correlation between the relative strength in the squat and the 400m showed a moderate negative correlation (r= -0.555,
The results show that the relative weight lifted in the squat correlated with faster time in the 400m freestyle swim where 30% of the variation in time of 400m could be explained by changes in the squat (table 2, figure 5).

![Figure 5](image)

**Figure 5.** The correlation between the relative weight in the squat and the time in 400m freestyle ($r=-0.555$)

### 3.3 Best predictor of time in freestyle

To explain which variable of the relative strength in the lat-pulldown, squat, height and sex differences contributed the most to the time in 50m and 400m freestyle, a multiple linear regression was done. Each variable was added separately, in a crude model, due to the low number of participants, n=14 in 50m and n=12 in 400m (table 3).

In 50m freestyle performance, 31% of the variation in time could be explained by the relative muscle strength in the lat-pulldown. With each 1kg/BW increase in the lat-pulldown the time in 50m decreased by 4sec (table3). Neither relative muscle strength in the squat ($r^2=0.16$, $\beta=-4.0$, $p=0.086$) nor height ($r^2=0.2$, $\beta=-0.1$, $p=0.064$) showed any significant contribution to the time in 50m freestyle (table 3). In addition, the multiple regression analysis showed that the variable sex could explain 54% of the men’s time in freestyle with reduction of 2.4sec in time compared to women (table 3).

The relative strength in lat-pulldown had the biggest contribution to the time in 400m ($r^2=0.25$) with 42.3% ($\beta=-42.3$; $p=0.057$) decrease in time, however, none of the four variables; squat, lat-pulldown height or sex, significantly contributed to the variation in 400m freestyle swim (table 3).
Table 3. Results of the linear regression, as a crude model, of what variable contributing to swim performance in 50m and 400m. The result is presented as unstandardized Beta-estimate ($\beta$-est), adjusted $r^2$, 95% confidence interval (CI) and p-value (n=12-14)

<table>
<thead>
<tr>
<th>Distance</th>
<th>Variable</th>
<th>B-est</th>
<th>$r^2$</th>
<th>CI (95%)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>50m</td>
<td>Lat-pulldown (kg/kg BW; %)</td>
<td>-4.8</td>
<td>0.31</td>
<td>(-8.9; -0.8)</td>
<td>0.024</td>
</tr>
<tr>
<td></td>
<td>Squat (kg/kg BW; %)</td>
<td>-4.0</td>
<td>0.16</td>
<td>(-8.7; 0.7)</td>
<td>0.086</td>
</tr>
<tr>
<td></td>
<td>Height (cm)</td>
<td>-0.1</td>
<td>0.20</td>
<td>(-0.2; 0.0)</td>
<td>0.064</td>
</tr>
<tr>
<td></td>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Women(n=10)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Men(n=4)</td>
<td>-2.43</td>
<td>0.54</td>
<td>(-3.7; -1.1)</td>
<td>0.002</td>
</tr>
<tr>
<td>400m</td>
<td>Lat-pulldown (kg/kg BW; %)</td>
<td>-42.3</td>
<td>0.25</td>
<td>(-86.1; 1.5)</td>
<td>0.057</td>
</tr>
<tr>
<td></td>
<td>Squat (kg/kg BW; %)</td>
<td>-39.2</td>
<td>0.24</td>
<td>(-80.6; 2.2)</td>
<td>0.061</td>
</tr>
<tr>
<td></td>
<td>Height (cm)</td>
<td>-0.1</td>
<td>0.10</td>
<td>(-1.2; 0.9)</td>
<td>0.817</td>
</tr>
<tr>
<td></td>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Women(n=9)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Men(n=3)</td>
<td>-12.65</td>
<td>0.77</td>
<td>(-33.0; 7.7)</td>
<td>0.197</td>
</tr>
</tbody>
</table>

BW = Body weight

4.0 Discussion

In the 50m freestyle swim there was a moderate correlation to the absolute strength in the lat pulldown and a high correlation in the squat. The relative strength and the time in 50m had a moderate correlation to the upper body. In the 400m freestyle swim was there a moderate correlation to both the upper- and lower body in relative strength. When analyzing which variable contributed the most to the relative strength in the lat-pulldown was the biggest contributor. The male sex had advantages over women in swim times.

4.1 Sprint

The result in the current study showed a moderate correlation ($r=-0.513$) between the absolute strength in the lat-pulldown and the time in 50m. Previous research have found stronger correlations ($r=0.93$) in the upper body strength and sprint performance (Smith, Norris &
Hogg, 2002) and \( r = 0.82 \) (Hawley et al., 1992) showing that the present results have a lower correlation coefficient than previous research. The differences between the studies and the present study may depend on a different age group and/or the smaller number of participant in the present study. In the study by Smith et al. (2002) the participants were older and competed in a higher level. The results from previous and the present study indicates that if a swimmer pulls down a lot of weight in the lat-pulldown it will result in faster times in sprints. The result can also be used in the other way around for evaluation purposes. The power output have been shown to be a good indicator for performance and the mean propulsive power in the lat-pulldown correlated with time in 50m \( (r=0.68) \). The same researchers also found that the mean propulsive power in the beach press and lat-pulldown can be explained by 99% from the load in kg (Morouço et al., 2011).

The present study showed that 36% of the relative strength in lat-pulldown can explain the time in 50m with a moderate correlation \( (r=-0.599) \). Previous research found a significant correlation between the power in the upper extremity relative muscle torque and the 50m freestyle \( (r=0.573) \) and the relative elbow flexor muscle torque in itself accounted for 24% of the time in 50m (Gola et al., 2014). This strengthens the result from the present study with two moderate correlations with a similar percentage of explanation with this study slightly higher.

Many intervention studies have used the lat-pulldown as an exercise to improve the upper body strength in swimmers as well as the use of other exercises. Morouço et al. (2012) showed that 50m sprint times improved by 2.1% after the intervention which is similar to previous research (Strass, 1987; Trappe and Pearson, 1994; Girold et al., 2007; Aspenes et al., 2009). When the swimmer gets fatigued the sense of where the shoulder is and proprioception is reduced. By implementing strength training mainly in the external rotators of the shoulder the proprioception in the humeral head develops and will in turn enhance the stroke length and rate (Matthews et al., 2017). Studies have used tethered swimming as a methods to correlated with performance in 50m sprint, with positive outcome (Sébastien Girold et al., 2007; Morouço et al., 2011). The is also contradictory results to this stating otherwise (Aspenes et al., 2009).

The present study had a high correlation between the absolute strength in the squat and the time in 50m \( (r=-0.769) \), this demonstrates that the time in 50m can be explained by 59% from the squat. These results are strengthened by previous research showing that the start
performance and the time to 15m correlates to the 1RM in the squat ($r=-0.74$) and the time can be explained by 55% the absolute strength (West et al., 2011). The absolute strength shows that the stronger and more weight lifted in the squat will give faster time in sprints, which might be because of the start and turn which has showed to increase the performance where the swimmer can produce ground reaction force. The swimmer will spend less time on the starting block and at the turning-point in the pool, which gives advantages over the other swimmers (Bishop, Smith, Smith, & Rigby, 2009; Cossor & Mason, 2001; Fig, 2010; García-Ramos et al., 2016; Morais et al., 2013; West et al., 2011).

The present study showed that the relative strength in the squat and the time in 50m did not correlate ($r=-0.475$) which gives the absolute strength in the lower body more importance. This information is new to the field and should be further investigated before a statement can be made. A study found that when performing squat jumps the peak power production with external weight related to body weight correlated well to start performance (García-Ramos et al., 2016). As mentioned previously the start performance decrease the time in sprints.

### 4.2 Middle distance

In the current study there was a negative low correlation between the absolute strength in the lat-pulldown and the time in 400m ($r=-0.239$) and for the relative strength there was a moderate correlation ($r=-0.563$). This knowledge is new to the field and highlights the importance of the relative strength in the upper body for the 400m freestyle. An intervention study by Trappe and Pearson (1994) found that strength training with the use of pull-ups and dips improved the time in 365.8m freestyle swimming. The present study the showed that with 31% of the relative strength in the lat-pulldown can explain the time in 400m. This is strengthened by the result from Aspenes et al. (2009) showing that after 11 weeks of strength training combined with endurance training improved the power production increased and the swimmers muscle strength by 20.3% and the time in 400m freestyle swim improved by 6.9%.

In the current study the absolute strength in the squat had a low correlation to the 400m freestyle ($r=-0.478$) and in the relative strength the squat had moderate correlation ($r=-0.555$). The fact that the squat relative strength had a moderate correlation to performance in the middle distance could be valuable information for all swimmers and coaches. No previous study has investigated absolute or relative strength in the squat and its correlation to 400m freestyle. However, a study looking at lower body power output found that the Wingate
Anaerobic test in the lower body did not correlate to the 400m freestyle performance (Hawley et al., 1992). On the other hand, the maximal sustained power output in the upper body did correlate to 400m freestyle ($r=0.70$) and this is contradictory result from the present study.

### 4.3 Best predictor to time in freestyle

In the current study the lat-pulldown was the best predictor to the time in 50m freestyle where each 1kg/BW increase in the lat-pulldown decrease the time in 50m by 4sec. In the 400m freestyle none of the variables (relative strength in lat-pulldown and squat, height and sex) contributed significantly to the performance. This results is comparable to previous research which found that the main power production comes from the upper body (Bucher, 1975; Hollander, de Groot, & van Ingen Schenau, 1988) with around 90% compared to the legs Morris et al. (2016).

In the present study the male sex was compared to the female sex in all of the variables (relative strength in lat-pulldown and squat, height and sex) and the time to 50m and 400m freestyle swim. The result showed that the male sex had advantage over women in the 50m with 54% chance of performing better 50m freestyle but not in the 400m freestyle. The difference in swim time between men and women were less in 400m compared to 50m and could be because of the energy effectiveness for the women in the middle to longer distances (Knechtle, Rosemann, Lepers, & Rüst, 2014) and the advantage for men in the 50m because they have more upper body mass (Gallagher & Heymsfield, 1998; Janssen et al., 2014). The difference between men and women could also be the low number of male participants, in the analysis there was only three men, which makes this comparison less accurate. If there had been more men in the study the difference between men and women could have been larger, but with only three men the data still showed some difference between the sexes.

In the present study the height contributed more to the time in 50m with a trend to be significant ($p=0.067$) but not in the 400m showing that if you are a taller person there is a chance of faster time in the 50m sprint. This is similar to the findings from Morais et al. (2013) where the anthropometrics had a connection to the swimmers competing level in all of the variables; body mass, height, trunk transverse surface area, arm span, foot surface area and hand surface area, indicating that the taller they were the better chance of a faster time in freestyle (eta-squared $= 0.35$). The study by Morais et al. (2013) used younger participants compared to the present study. This might indicate that the height contribute more in younger
swimmer then in older.

4.4 Methodological Discussion

The present study aimed to determine the strength of the upper- and lower body and its correlation to the time in 50m and 400m freestyle, and which variables contribute the most of upper- and lower body strength, sex and height to performance. The method in the present study for strength assessment has been used in previous research (West et al., 2011) and the 3RM method was used instead of 1RM to minimize the stress on the participants’ muscles. The fact that many of the participants were not used to perform a maximal strength test could have influence the results of the study. Some of the participants were more experienced in the gym and with the squat and lat-pulldowns, whereas others did not have as much experience and this could have affect the result of the study by a large range between min and max. The use of pull-ups could have been an alternative but since the pull-up is a more difficult exercise to perform it was reasoned that in a group with varied experience with strength training the lat-pulldown would be a more appropriate exercise.

The present study used stopwatches to measure time in the 50m and 400m freestyle. Stopwatches are valid and reliable tools with no significant difference between the electronically measured times Hetzler et al. (2008) however, in a swimming competition the touchpads are often used instead (Sage, 2013). The use of stopwatches in previous research have been used in Trappe & Pearson (1994); Dragunas, Dickey & Nolte (2012) while some used electronic touchpads (Song, Park & Jting, 2009). In the present study the use of stopwatches was used to make it easier to implement even if they may show slightly faster times (0.04 to 0.05 seconds) (Hetzler et al., 2008). To be more precise the use of two stopwatches and coaches would have been more reliable but the difficulty of getting several coaches with good experience was hard. Each swimmer had one coach or test leader, and these were experienced in using the stopwatch because they use them almost daily.

The test was done in a pool around a temperature of 28°C and this is in between the limits for normal regulatory functions for the human body. The temperature in the water did therefore not affect the results of the study. It is stated that the optimal temperature for endurance performance should be between 25°C to 27°C for sprint the temperature should be around 27°C to 29°C (Alexiou, 2014).
4.5 Practical application

The 50m freestyle showed a moderate correlation to the lat-pulldown and a high correlation to the squat in absolute strength highlighting that the strength in the squat is of importance as this might have an impact on start and turn performance. The relative strength is of more importance in the 400m as this study showed moderate correlation in both the upper and lower body. The result in this study showed men have a bigger chance of performing better in the 50m sprint compared to women, but not as much in the 400m. In the current study the upper body had moderate correlation in both the absolute and relative strength and in both the distances showing that the upper bod are the main contributor to performance in general.

5.0 Conclusion

The absolute strength in the squat had a high correlation to the time in 50m freestyle swim, which supports previous literature and underlines the importance of lower body strength and 50m freestyle swim performance. For the 400m there was a moderate correlation to the relative strength in the squat and lat-pulldown showing that for the overall performance in middle-distance the relative strength has the advantage over absolute strength which is new information to the field. This gives future research the potential to further investigation in the area. The relative and absolute strength in upper body correlated to both 50m and 400m freestyle and could therefore strengthen the importance of upper body strength in sprint and middle distance as previous researchers has stated. The upper body strength is the best predictor of time in 50m.
6.0 References


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Janssen, I., Heymsfield, S. B., Wang, Z., Ross, R., Kung, T. a, Cederna, P. S., … Dysinger,


Ageing.


7.0 Appendix

7.1 Informed consent

Information to participants in ”Upper- & lower body strength and performance in freestyle swimming”

Prestation inom simning beror på flertalet faktorer och överkroppsstyrkan har visat sig ha betydelse på korta distanser som 50m frisim. Hur underkroppsstyrkan påverkar är fortfarande oklar. Tekniken är en viktig faktor för prestationen på medel till längre distanser medan styrka och explosivitet är två viktiga faktorer på korta distanser. Syftet med denna studie är att se om det finns ett samband mellan prestation och över- och underkroppsstyrka i 50m och 400m frisim.


Fördelarna med detta är att du som deltagare kommer få dina testresultat både i knäböj och i ryggdrag samt få testa din nuvarande tid på 50m och 400m frisim. Du kommer som deltagare även kunna ta del av resultatet från studien i framtiden genom att kontakta ansvarig.
Risker med studien är att stressen på dina muskler kan bli hög under dina maxtester i knäböj. Dessa kan vara svåra att utföra men de kommer noga övervakas av testledaren. Vid bristande teknik kommer testet att avbrytas.


Ditt deltagande i studien är frivilligt och du kan utan anledning avsluta ditt deltagande utan förklaring och detta kommer inte påverka dig eller din fortsatta kontakt med tränare eller testledare. Om du väljer att avsluta ditt deltagande så kan du om du önskar få den redan insamlade datan raderad.

Ansvarig:
Julia Björk
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Handledare:
Emma Haglund
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Informerat samtycke
- Jag bekräftar att jag har tagit del av informationen och syftet med studien "över- & underkroppsstyrka och prestation i simning" både muntligt och skriftligt. Jag har också fått tillfälle och ställa frågor om mitt deltagande.
- Jag ger mitt samtycke att delta i studien och jag är fullt medveten att det är frivilligt och att jag kan avbryta mitt deltagande utan förklaring. Önskar jag, kan redan insamlad data förstöras.
- Jag tillåter att data samlas in enligt den information jag tagit del av och att den kommer förvaras och hanteras av den som är ansvarig av studien.
- Jag är medveten om att deltagande i studien sker på egen risk.

Deltagare:

_________________  __________________  __________________
Datum                Signatur             Namnförtydligande

________________
Födelsedag

Om testpersonen är under 18 år krävs målsmans namnteckning.

_________________  __________________  __________________
Datum                Signatur             Namnförtydligande

________________
Födelsedag

Ansvarig:

_________________  __________________  __________________
Datum                Signatur             Namnförtydligande
7.2 Questionnaire

Frågeformulär

Namn: Ålder:

Favoritsimsätt:

Favoritdistansen:

Tid på 50m frisim:

Tid på 400m frisim:

Hur många tillfällen tränar du i snitt per vecka:

Hur många timmar tränar du i bassängen per vecka:

Hur många timmar är land träning/styrketräning: