Effects of two different strength-training methods to improve adolescents’ physical soccer performance

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Master Thesis 30 credits in Sport and Exercise Science – Human performance

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Abstract

**Background:** Strength training for children and adolescents was for a long time a controversial subject but is nowadays proven safe and beneficial and recommendations for children’s strength training have been put forward by scientific sports boards in several western countries. Despite that, in Sweden strength training is not very commonly applied in children and adolescent’s sport. Strength training has proven to increase the sports performance and decrease the risk of injuries both in adults and children and would therefore be a good additional training method to the sport-specific training at any age. Different types of strength training have in several studies shown to improve the jumping ability, sprint performance and several other aspects. **Purpose:** The aim of the present study was to investigate the differences between pre- and post-test for the physical performance test after the 8-week strength training intervention both for the whole training group together and divided by type of intervention. **Method:** Eighteen adolescent boys were divided in two strength training groups, a friction Flowin® training group (FTR) and a barbell training group (BTR). They were tested pre and post an eight weeks intervention for 5-10-30 m sprint, Agility zig-zag test and two different counter movement jump (CMJ) tests. **Result:** The 30 m sprint improved after 8 weeks intervention for both groups together (n=18) (p= 0.036). Splitting into groups based on intervention, only the BTR group improved their performance in 30 m sprint after 8 weeks intervention (p=0.036). Both the BTR and FTR decreased their performance in 5 m sprint after the 8-week intervention (BTR p=0.007, FTR p=0.014). There was no statistical significant difference between or within the groups regarding any other tests. **Conclusion:** Eight weeks of strength training can improve the 30m sprint performance for adolescent male soccer players after 8 weeks intervention. More research is needed to conclude whereas the increase and explosive performance for adolescents are more affected by the duration of strength training or the strength training methods.

**Keywords:** Children, adolescent, strength training, Flowin, barbell, physical soccer performance
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1. Introduction

Strength training for children and adolescents was for a long time considered a controversial subject, believed to cause injuries and future damage, but is nowadays proven a safe training method for children when properly supervised and designed (1, 2). Research has shown a multitude of benefits from strength training for children and adolescents, including for example increased bone density, decreased risk of injuries, increased fat free mass, improved cardiovascular risk profile and improved motor performance skills (1, 2). Children as young as 5-6 years old have been shown to gain benefits from regular participation in strength training (1). The general guideline for when to begin to participate in strength training, is when the child is mature enough to understand and receive instructions (1, 2).

A quite unanimous research body declaring strength training to be beneficial for children if conducted properly. The only information to be found from the Swedish Sport Association (Riksidrottsförbundet) is a brief report about strength training with children, along with the recommendations for strength training with children from the US, UK, Canada and Russia. (3). The implementation of actual strength training for children in sports in Sweden is not very common despite scientific evidence of its beneficial effect both from studies conducted in Sweden (4) and abroad (1). A recent strength training program from the Swedish soccer association is the “Knäkontroll-program”, a neuromuscular strength training program for female soccer teams to decrease the risks of anterior cruciate ligament (ACL) injuries in female soccer. This can be seen as an important step to promote strength training in Swedish sports culture for children and adolescents but more information is needed.

Thus, the general aim of this study was to investigate the effect of two different types of strength training methods (Barbell and Flowin®) on physical soccer performance in young adolescent boys with no previous experience in strength training.

2. Background

The two most commonly used terms for training to increase the muscle strength of the body are strength training and resistance training. The term resistance training is mainly used to describe activities that include lifting an extern weight such as a barbell, dumbbell, medicine ball, body weight, augmented body weight or machines. The term strength training is more often used to include both resistance and all other different methods to increase the strength as
plyometric, agility, flexibility, etc. (5). In this thesis the term strength training will be used to include a wider category and include both barbell training and friction training.

2.1. Increasing the strength of skeletal muscles
The force production ("strength") in a human skeletal muscle can be increased in different ways, one is by the neurological adaptation, which depends on muscle motor units recruitment and synchronization, which for adults, tend to occur primarily during the first 8-10 weeks during the beginning of a strength training program (5). Another way for adults to increase strength is by muscle hypertrophy, which is primarily due to increased muscle fiber size in the muscle (6). In comparison, the main factor for strength increases for children and adolescents has been found to be by the neuromuscular pathway (1, 2, 5). For children to increase their strength through hypertrophy is more difficult compared to adults since they do not produce the same levels of the testosterone hormone, which is needed for significant hypertrophy to occur. (5).

In children and adolescents, one of the most important factors for an increase in strength is an increased motor unit activation (7), however, what training method is best suited to stimulate healthy strength increases in children and adolescents are not yet determined. Studies looking at strength gain in children and adolescents have used different equipment; for example, adult and/or child-sized weight machines (1, 2), elastic tubing (8), power bags (9) and free weights (10). Variations in volume and intensity have been investigated, (1, 11) where for example Faigenbaum et al (11) found in an study with 5-12 years old children, that strength training with child-sized machines, and 1 set of 13-15 reps, was more beneficial than 1 set of 6-8 reps.

A study on male soccer players (11-19 years) showed that children and adolescents have a high capacity to increase strength (10). The study compared two groups, where one group added strength training with free weight twice a week (squats and other exercises) to their regular soccer training, whereas the other group only participated in their regular soccer training. After approximately 2 years intervention, the strength and soccer training group had statistically significant higher strength values in both 1 repetition maximum (1RM) squat and 1RM related to body weight (SREL), compared to the soccer only control group. A study done with girls used simple body weight exercises to train the knee movement pattern, the result showed that the simple neuromuscular training could decrease the risk of ACL-injuries (4).
Some studies have also indicated that the lower body is more trainable than the upper body for children. (11). Even though pre-pubertal children can not increase their muscle mass in the same way as an adult or post-pubertal adolescent due to less testosterone in the blood, research has shown an increase of testosterone production after a training intervention during 2 months, (3 times per week, 10 repetitions, 3 sets) with resistance machines for boys 11-13 years (12).

Research has also indicated that participation in strength training or regular sports increases strength more than for non-active children and adolescents. Christou et al. studied the physical development over 16 weeks of 12-14 year old boys in respect to different training methods by dividing up the boys into one soccer only group, one soccer and strength training group and one group which did not participate in any sport. Results showed that the soccer and strength training group increased their lower body strength, sprint performance, jump performance and agility, the soccer only group improved agility, whereas the non-sports group showed no statistically significant improvements during the same time (13).

2.2. Body development during puberty and biological age

Children mature differently and their biological age does not always match their chronological age. A child’s development can be divided into three phases; pre-pubertal age, pubertal age and post-pubertal age (5, 14). The pubertal phases are linked to different physiological development areas and thus different possible adaptations to training. During the pre-pubertal phase strength increases are predominantly due to neuromuscular factors for children (14). However in recent years, a few studies have shown small increases in hypertrophy alongside increases in neurological adaptations during the pre-pubertal phase (5, 12).

In the pubertal phase children develop both physiologically and psychologically, since the nervous system is not fully developed until puberty, the pubertal phase brings physiologically increases in muscle mass, through alterations in the nervous system, development of muscle fascia and increases in nerve myelination. This allows the child to develop their training and muscular strength since the muscle contraction is caused by nervous signals. The myelination
is closely related to the nervous system electricity and is there for affects the velocity of the impulse (15).

In the post-pubertal phase, the late phase of puberty the body is more susceptible for muscle hypertrophy. This creates very favourable conditions to develop and increase the hypertrophy, mainly because the increases in hormones, this is mainly caused by the increased hormone production of testosterone. The potential for muscle hypertrophy is larger for boys than girls, mainly depending on the higher production of testosterone in boys (14).

The biological age can be estimated using different published methods (14). One commonly used method is the Tanner scale, which assesses biological age by studying the genitals. The Scale has a good correlation to the child’s real biological age and is the most frequently used method to assess the biological age (16). Other methods rely on anthropometric data, for example the Körperbauentwicklungslingsindex, (KEI), which measures the body proportions (shoulder with, hip with, the circumference of the underarm, weight and height) and uses a formula to calculate biological age. The method has a correlation coefficient of $r > 0.89$ (14, 17). LTAD (Long Term Athlete Development) measures the proportions between the legs and the over body length in standing and sitting positions to assess the biological age and pubertal stages. (14, 18).

### 2.3. Physiological demands for soccer players

Soccer is the largest sport in the world, played by adults, children, women and men. The sport require a lot of different abilities such as running, sprinting, jumping, shooting, tackle, flexibility, stability, strength, power and endurance (19, 20). An adult player moves from 9-14 kilometres (km) during a game and a goalkeeper about 4 km. The movements contain both standing, walking, running in different modes and sprint forwards and backwards (21). 96% of the sprints during a soccer game are shorter than 30 meters (m) and 49% shorter than 10 m. A sprint for an outfielder occurs approximately every 90 seconds (19). No evaluation of the movement pattern for children in soccer has been made.

### 2.4. Training methods: Friction training and free weights

Up to date very little research has been conducted on friction training, training that uses two different materials, which creates friction, resistance when pressured against each other. Two of the available training equipment for friction training in the market is the Flowin® mat and
the Slideboard. The Flowin® concept includes a mat placed on the floor with special surface and smaller pads onto which the exerciser can place different body parts in order to create a sliding motion horizontally across the plate that creates friction. The exerciser is able to fully master the friction by altering the amounts of pressure on the pads. Flowin® concepts offer exercises that targeting stability, mobility, strength, balance, speed and power according to their own website (22). No study to date has looked at friction/sliding training in children.

Free weight exercise is a very common training method to increase the strength with additional weight such as barbells, dumbbells and weight plates. Training with free weight means to move your own body and the additional weight in different directions, usually upwards or sideways. Lifting free weights is also considered to be an more natural training method than for example machines since it’s not isolating single muscles (23).

2.5. Strength and physiological sport performance

Common ways to measure the effect of strength training on physical performance are sprint, jump and change of direction (agility) tests, also called field tests. Many studies have shown that associations exist between 1RM strength and jumping and sprint-tests for children and adolescents (1, 24, 25). In addition improvements in motor performance skills such as long jump, vertical jump, sprint speed, and medicine-ball toss have been seen after strength training programs (1). To assess the strength of children and adolescents different tests have been used in previous studies including field tests (agility, jump, sprint) (13, 24) and local muscular endurance and muscular strength tests (1RM, 5RM tests) (12, 13, 24).

Increases for sprint (9, 13) and vertical jumps (9, 13, 26, 27) have been found in several studies after strength training, notable is however that the sport performance has been higher with addition of plyometric training or sprint training together with the resistance training (9, 28, 29). Studies have also shown that sport specific training and strength training together gains higher improvements in performance than only one of the training methods alone (13, 29).

Research with agility for adult has indicated that the connection between sprint, acceleration and strength training, is not the same for performance increases in agility (30). A recent study has, on the other hand found correlations between agility, 1RM squat strength and improvements in agility after 2 years of additional strength training to the soccer training with
15-17 year old adolescent males. That finding might conclude that strength training can improve the performance of agility but after a longer period of training (24).

No special tests for testing children’s maximum strength have been found during the research. Testing children to assess their muscular strength are considered safe and valid (31), research has shown that even 1RM test is considered safe and effective with appropriate equipment and procedures, using similar methods to testing adults for 1RM (1, 31, 32).

For adults the correlation between strength training and sport performance is well established and known since several years (33). For example a higher 1RM in squat is associated with higher jump height and faster sprint speed (33, 34). This correlation has, during the past years, been studied in children and adolescents as well with similar results. A Recent study investigated correlations between strength, jumps and different sprint speed distances for junior male soccer players. The study found high correlations between CMJ and 30-100 meters sprint, however for accelerations and 5 meter sprint, SJ and 1RM half back squat showed higher correlations (25). Thus, we now know there are benefits from strength training with different types of equipment for adult and for children and adolescents evidence is building up. However it is still very inconclusive regarding the best strength training method, why the subject of the thesis was strength training for children and adolescents.

2.6. Aim

The aim of the present study was to investigate effects of eight weeks of either barbell strength training, or friction based strength training on physical soccer performance test, (sprint, agility, power) in adolescents male soccer players with no previous experience in strength training.

Specific research questions:
- Does an eight week strength training intervention (independent of intervention method) improve sprint, agility or jump performance?
- Does an eight week barbell strength training intervention improve sprint, agility or jump performance?
- Does an eight week Flowin® strength training intervention improve sprint, agility or jump performance?
3. Methods

3.1. Subjects

The subjects participating in the study were adolescent male soccer players from the same club, (n=26). During the 8-week intervention study, the subjects were required to participate in at least 10 of 16 training occasions and not be absent for more than four training occasions in a row, in order to be included in the study (arbitrary limit). Eight players were excluded from the analysis because of too many missed training sessions. The total number of subjects included in the analysis were 18 boys. The chronological age of the remaining 18 players were, 12-14 years (mean age 13±1), mean height 165±9 centimetres and weight 48±7 kilograms. After a test of the biological age (KEI) the original 26 subjects were divided into the two training groups where average biological age was the same in each group (Equation 1). Half of the subjects were placed in the Flowin® friction based training group (FTR) and the other half of the subjects in the barbell-training group (BTR). At the start of the study, the players were in their off-season and had regular soccer training two times a week. None of the subjects had participated in strength training before the intervention. Since no subjects in the same age with similar training could be found in the same time-period, no control group was used. No subject was injured during the study-period.

Table 1: subject characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>All subjects (n=18)</th>
<th>BTR (n=9)</th>
<th>FTR (n=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronological age</td>
<td>13±1</td>
<td>13±1</td>
<td>13±1</td>
</tr>
<tr>
<td>KEI Index</td>
<td>0.608±0.071</td>
<td>0.615±0.074</td>
<td>0.608±0.071</td>
</tr>
<tr>
<td>Height, cm</td>
<td>165±9</td>
<td>163±10</td>
<td>163±9</td>
</tr>
<tr>
<td>Weight, cm</td>
<td>48±7</td>
<td>48±7</td>
<td>48±7</td>
</tr>
</tbody>
</table>

BTR = Barbell Training Group, FTR= Flowin Training Group

3.2. Tests

The subjects were tested pre and post an 8-week strength training intervention for sprint, agility and jump height, and all tests were performed indoors in a sports hall. The biological age, tested with the KEI method, measuring shoulder width, hip width, underarm (widest part), weight (kg) and height (cm) (14). The values were then calculated according to the KEI formula (Equation 1) to estimate their biological age.
The KEI formula for boys to calculate the biological age =

\[
(\text{shoulder width (cm) + hip width (cm)}) \times (2 \times \text{underarm (cm)} - 16 \text{RI}) \\
+ 18.1) / 20 \times \text{body length (cm)}
\]

\(\text{RI}= \text{Rohrers Index (Bodyweight (g) x 100 / Body Length cm}^3\)

**Performance tests**

The sprint test 5-10-30 meter with standing start, just behind the start line, was performed with photocells (MuscleLab, Ergotest Innovation, Porsgrunn, Norway), which measured the time. The subjects performed the sprint 3 times with at least 3 min rest between trials, the best time from all the three different measure point was recorded for analysis. The agility zig-zag test (30, 35, 36) was performed with photocells (MuscleLab, Ergotest Innovation, Porsgrunn, Norway), that measured the time. The photocells were placed at the start and end of the test. The test was performed twice and the best trial was used for analysis. The test was performed with 5 meters sprint between cones and the angle between the cones was 110 degrees. The total distance was 20 meter. The subjects rested about 3 minutes between the trials. The tests are considered to have high reliability (35).

Counter movement jump was performed both with and without arm swing and jump height was measured with infrared lights (IVAR Testsystem, LN Sport Konsult HB, Mora, Sweden). Each subject performed three jumps of each test and the best was recorded for analysis. Both test is considered having high reliability and validity (37).

**3.3. Training**

Both training groups performed their strength training routine at the same time twice a week in non-consecutive days with their different equipment and exercises. In addition to their strength training the subjects had two soccer practises a week. The subjects had one week of rest during Easter according to the school holidays. Before each strength training session a warm-up was performed together in the two groups including mobility exercises, movement without any added weight and a stability exercise (38). Both strength training programs were constructed to contain the same movement patterns as far as possible to be comparable (table 2).

The subjects in the FTR friction based training group performed all their exercises on a Flowin® mat with 15 repetitions and 3 sets for each exercise during the whole training period. They were encouraged to increase the resistance by adding more of their own body weight
against the plate and in that way increase the friction and thus resistance. Some of the exercises were increased with a longer lever arm to increase the resistance of the exercise. The exercises used in the training program are shown in table 2.

The subjects in the barbell group began their training intervention with 15 repetitions and 3 sets performing their exercises with only the barbell that weighed 8 kilograms (kg) and was child-sized. After 3 weeks, when the subjects performed the exercises with good technique and felt secure about the exercises, they were allowed to add weight with weight plates. The subjects chose their added weight themselves after their own strength level. They were encouraged to choose the weight where they were able to perform no more than 15 repetitions with proper technique. For the last three weeks of the intervention program, the exercises were performed with only 10 repetitions and three sets but with higher weight added to the bar and the same instructions with weight appropriate for 10 repetitions. The exercises performed for the BTR group are shown in table 2.

<table>
<thead>
<tr>
<th>Table 2: Exercises for FTR and BTR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowin exercises</td>
</tr>
<tr>
<td>Forward lunge</td>
</tr>
<tr>
<td>Lateral Squat</td>
</tr>
<tr>
<td>Lateral Slide</td>
</tr>
<tr>
<td>Raske (standing stability exercise)</td>
</tr>
<tr>
<td>Curtsey Lunge</td>
</tr>
<tr>
<td>Flow out on forearms</td>
</tr>
<tr>
<td>Prone Pike Push-up</td>
</tr>
<tr>
<td>Mountain Climber</td>
</tr>
</tbody>
</table>

BTR = Barbell Training Group, FTR = Flowin Training Group

3.4. Social and ethical considerations

All the subjects and their parents were informed about the procedure of the study; that they at any time could withdraw from the study and what risks and benefits that might come from participating in the study. Both the subjects and their parents signed a written consent to participate in the study. The subject was not mentioned or analysed by their own name in the research or with any pictures according to the personal data act. There was no risk for the subjects to participating in the study.

3.5. Statistical analyses

The statistics were performed in the program IBM SPSS 20 statistical analysis software (SPSS Inc., Chicago, IL, USA). The data was checked for normality with the Shapiro-Wilks
test and found to be normally distributed, and thus parametric analyses were used. The pre- and post-tests for the physical performance tests for all the subjects were compared with a paired sample t-test. An independent t-test was used to see if there were any differences between the two training groups pre or post the intervention. An alpha of P<0.05 was considered statistically significant for all comparisons.
4. Results

4.1. Differences between the Barbell and the Flowin training groups

There was no statistical significant difference between the groups (BTR and FTR) regarding biological age (p=0.08), length (p=0.25) or weight (p=0.14) before the intervention started (n=18). There was no statistical significant difference between the groups regarding the physical performance tests before the intervention, which means that the groups had the same baseline values; 5 m sprint p=0.44, 10 m sprint p=0.21, 30 m sprint p=0.24, CMJ p=0.14, CMJ swing p=0.27, zig-zag agility p=0.47. The physical performance tests showed no statistical significant difference between the groups after the eight weeks intervention; 5 m sprint p=0.84, 10 m sprint p=0.51, 30 m sprint p= 0.35, CMJ p=0.40, CMJ swing p=0.61 and zig-zag agility p=0.43, mean values for pre- and post sprint-test is shown in figure 1.

Differences due to intervention for both training groups together (n=18), the 30 m sprint test statistically significantly improved (p=0.036) after the intervention, whereas the 5m- and 10 m sprint showed a statistically significant decrease in performance. None of the other physical performance test showed any statistically significant results from pre to post-test after the strength training programs (table 3).
4.2 Differences due to intervention within groups

When comparing the two strength training programs individually (BTR n=9, FTR n=9), this study found that the BTR increased their performance statistically significantly for the 30 m sprint test after the 8 weeks intervention (p=0.036), but statistically significantly decreased their performance for the 5 m sprint test (table 4). The FTR showed no statistical significant increases in performance after the 8 week intervention but instead decreased their performance for the 5- and 10 meter sprint test (p=0.014 and p=0.018), as shown in table 4.

Table 2: Mean values (± standard deviation) pre- and post-tests for both groups together (n=18), and difference between pre- and post-tests (p-value)

<table>
<thead>
<tr>
<th>Test</th>
<th>Pre-test value</th>
<th>Post-test value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 meter sprint (s)</td>
<td>1.00 ± 0.07</td>
<td>1.05 ± 0.07</td>
<td>&lt;0.001  †</td>
</tr>
<tr>
<td>10 meter sprint (s)</td>
<td>1.81 ± 0.13</td>
<td>1.86 ± 0.12</td>
<td>0.008 †</td>
</tr>
<tr>
<td>30 meter sprint (s)</td>
<td>4.78 ± 0.41</td>
<td>4.71 ± 0.32</td>
<td>0.036 *</td>
</tr>
<tr>
<td>CMJ (cm)</td>
<td>28.59 ± 4.28</td>
<td>28.73 ± 4.59</td>
<td>0.845</td>
</tr>
<tr>
<td>CMJ Swing (cm)</td>
<td>35.04 ± 6.17</td>
<td>34.55 ± 5.42</td>
<td>0.563</td>
</tr>
<tr>
<td>Zig-zag agility (s)</td>
<td>5.13 ± 0.30</td>
<td>5.12 ± 0.27</td>
<td>0.822</td>
</tr>
</tbody>
</table>

* Statistically significantly different from pre-training values with increased performance (P < 0.05)
† Statistically significantly different from pre-training values with decreased performance (P < 0.05)
CMJ = Counter Movement Jump

<table>
<thead>
<tr>
<th>Test</th>
<th>Mean values Pre-test</th>
<th>Mean values Post-test</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-meter sprint (s)</td>
<td>1.02 ± 0.09</td>
<td>1.06 ± 0.09</td>
<td>0.007 †</td>
</tr>
<tr>
<td>10-meter sprint (s)</td>
<td>1.86 ± 0.17</td>
<td>1.88 ± 0.15</td>
<td>0.235</td>
</tr>
<tr>
<td>30-meter sprint (s)</td>
<td>4.90 ± 0.55</td>
<td>4.79 ± 0.43</td>
<td>0.036 *</td>
</tr>
<tr>
<td>CMJ (cm)</td>
<td>27.09 ± 4.05</td>
<td>27.80 ± 4.34</td>
<td>0.322</td>
</tr>
<tr>
<td>CMJ Swing (cm)</td>
<td>33.40 ± 6.03</td>
<td>33.87 ± 5.87</td>
<td>0.655</td>
</tr>
<tr>
<td>Zig-zag agility (s)</td>
<td>5.19 ± 0.40</td>
<td>5.18 ± 0.35</td>
<td>0.877</td>
</tr>
</tbody>
</table>

Table 3: Mean values (± standard deviation) for pre- and post-test divided by training groups (n= FTR=9 BTR=9).

<table>
<thead>
<tr>
<th>Performance test</th>
<th>Mean values Pre-test</th>
<th>Mean values Post-test</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARBELL</td>
<td>5-m sprint (s)</td>
<td>1.02 ± 0.09</td>
<td>1.06 ± 0.09</td>
</tr>
<tr>
<td></td>
<td>10-m sprint (s)</td>
<td>1.86 ± 0.17</td>
<td>1.88 ± 0.15</td>
</tr>
<tr>
<td></td>
<td>30-m sprint (s)</td>
<td>4.90 ± 0.55</td>
<td>4.79 ± 0.43</td>
</tr>
<tr>
<td></td>
<td>CMJ (cm)</td>
<td>27.09 ± 4.05</td>
<td>27.80 ± 4.34</td>
</tr>
<tr>
<td></td>
<td>CMJ Swing (cm)</td>
<td>33.40 ± 6.03</td>
<td>33.87 ± 5.87</td>
</tr>
<tr>
<td></td>
<td>Zig-zag agility (cm)</td>
<td>5.19 ± 0.40</td>
<td>5.18 ± 0.35</td>
</tr>
<tr>
<td>FLOWIN</td>
<td>5-m sprint (s)</td>
<td>0.99 ± 0.58</td>
<td>1.06 ± 0.67</td>
</tr>
<tr>
<td></td>
<td>10-m sprint (s)</td>
<td>1.78 ± 0.70</td>
<td>1.85 ± 0.70</td>
</tr>
<tr>
<td></td>
<td>30-m sprint (s)</td>
<td>4.67 ± 0.18</td>
<td>4.64 ± 0.18</td>
</tr>
<tr>
<td></td>
<td>CMJ (cm)</td>
<td>30.10 ± 4.18</td>
<td>29.68 ± 4.91</td>
</tr>
<tr>
<td></td>
<td>CMJ Swing (cm)</td>
<td>36.69 ± 6.21</td>
<td>35.24 ± 5.19</td>
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<tr>
<td></td>
<td>Zig-zag agility (cm)</td>
<td>5.08 ± 0.17</td>
<td>5.07 ± 0.18</td>
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</tbody>
</table>

* Statistical significantly different from pre-training values with increased performance (P < 0.05)
† Statistical significantly different from pre-training values with decreased performance (P < 0.05)
5. Discussion

After eight weeks of strength training the result showed a statistical significant increase in 30-meter sprint performance compared to the pre-test for the training intervention for both training groups together. When analysing the mean values for the group separately, the BTR statistically significantly improved their performance in 30-meter sprint time whereas the FTR did not.

5.1. Strength training and sprint

When all subjects were pooled as one strength training group (independent of strength training method) the 30-meter sprint test was statistically significant faster after the training period compared to the pre-test. To further investigate the results, the groups were separated, and data revealed that only the BTR had statistical significant shorter sprint time on 30 m sprint, and thus improved their performance. These results are in agreement with earlier research where the strength training for adolescents has shown to increase the running speed for 30 meter sprint (13, 29). Similar to our study, strength training in earlier research did not increase the shorter sprint time (13). It seems as if maximum sprint (30 m) is affected more by strength training in adolescents than acceleration sprint (5-10 m), which might be explained by the absence of explosive training like plyometric and sprint training for any of the training groups in our study. With addition of speed training, and/or plyometric training other research have also improved the jump-tests in addition to the 30 m sprint (9, 28, 29). Another test with correlation to shorter sprint distances is 1RM squat (25), which was not measured in this study. Our result could suggest that the training has not gained strength enough after eight weeks for the subjects to improve the shorter sprint distances, but only the 30 m sprint.

5.2. Strength training and jump height

In the present study we saw no change in jump height in either strength training group, neither for the CMJ, nor for CMJ swing. For adults and for older adolescents, research has shown a strong relationship between squat strength, sprint and vertical jump (33, 25). A study with adolescents performing heavy strength training up to 90 percentage of 1RM did improve their maximum strength but not their explosiveness (39). This result could be transferred to our study since the subject did increase their training load during the intervention but the 1RM was never measured. In contrast, Christou et al investigated 16 weeks of training with barbells and machines performed with 15-8 repetitions and 55-80 percentage of 1RM and found improvements in the performance in the jump tests in adolescents boys. The study also showed improvements for 30-meter sprint but not for 10-meter sprint in accordance to this
study (13). The main differences between this and our study is the duration of the intervention, Christou et al had the double time of intervention. Another difference is that they measured the squat resistance, and thus could control what resistance the subject were lifting each training session in accordance to their 1RM.

5.3. **Strength training and agility**
The present study showed no improvements in the zig-zag agility performance after the eight week intervention. This is in accordance to earlier research which has not revealed any improvements in agility with shorter strength training interventions, but after longer interventions of 2 years with strength training (24).

5.4. **Strength training differences between flowin and barbell**
Since it up to date has been done very little research on friction training and especially flowin®, this study can not give any concluding suggestions of Flowin’s effectiveness as a training tool. It can though bee suggested that eight weeks of Flowin® training is not enough to improve the physical performance tests measured in this study for adolescents.

If the 1RM squat had been measured during this study, conclusions could have been made regarding possible strength increases in the two training groups. In addition percentage of 1RM in the BTR group lifted during their training could have been calculated. Some speculations are that since the BTR increased performance in 30-meter sprint, which is correlated with a higher value in 1RM squats, could be an indication of increased strength during the 8 weeks of intervention. Since the FTR also had smaller, but statistically insignificant increases in 30 m sprint after the friction based strength training, it can be speculated that they might have increased their strength but maybe not as much as the BTR. This might have been shown better with other testing methods.

Another note is that the coach and players experienced more body awareness after the flowin-training than before. To test the motoric skills and body control would therefore also been an interesting addition to the testing protocol.

5.5. **Method discussion**
One of the methodological issues in the theses is the biological age of the subjects, which was close to show statistical significant difference in the groups. This could have several reasons, the biological age in puberty is known to differ, but also that the KEI method is not as reliable as the Tanner method that is the mostly used method to assess the biological age. According
to the KEI-test, some of the subjects in the study had not yet reached puberty, which would mean that they were unable to develop all the factors needed to improve the explosiveness due to the not fully developed nervous system (15). Another factor affecting the result is the duration of the intervention, the present study was performed during 8 weeks of strength training with a one week Easter break in the middle. Some other studies with similar strength training as the barbell program and similar ages, have shown statistical significant results for vertical jump but have used longer intervention periods, (12 and 16 weeks of intervention), (9, 13). The fact that the intervention groups only contained 9 subject in each group also decreased the chances of a statistic difference between the groups.

During the last month of the training the subjects had a lot of soccer games, this might have caused fatigue that affected the post-test result. According to earlier research the body is not fully recovered until about 48 hours after a soccer game (40, 41). The possible fatigue is therefore an aspect that could have affected the test results in a negative way. Earlier research has showed lower results for both sprint tests and jump tests after soccer games for both adults and adolescents (40, 41). Though the subjects in this study had a period of several matches, more than one game a week, this could be one reason for the lower results. The fatigue could explain the decrease in performance for the shorter sprint distances (5 and 10 m sprint). If this study had included a control group, it would have been possible to compare the control group to the two training groups to conclude a fatigue factor.

According to the Flowin® website, the equipment should offer training for stability, mobility, strength, balance, speed and power. The factors treated in this study are mainly strength, speed and power. Of those three strength and speed can be seen as factors that might be able to improve with flowin training. More research is needed to conclude and approve the statement of this research and use longer intervention periods as well as expanding test protocol used to see if it could affect the outcome result.
6. Conclusions

Eight weeks of strength training with Flowin® or barbell increased the 30-meter sprint performance in young adolescent boys, however, when divided by training groups only the BTR showed statistical significant increases for the 30 m sprint. Barbell training can be a good strength training method to increase the 30 m sprint performance for adolescent, male, soccer players with no previous experience in strength training to improve their physical soccer performance. More research is needed to conclude whereas the increase and explosive performance for adolescents are more affected by the duration of strength training or the strength training methods.
7. References


