A correlation study between vertical jump height and sprint in young female teamgymnasts

Emma Larsson

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# Table of Contents

Background .................................................................................................................. 1

Physiology of the muscles ......................................................................................... 2

Jump and plyometric training .................................................................................... 3

Sprint .............................................................................................................................. 4

Associations between vertical jump and sprint ......................................................... 5

Aim ................................................................................................................................. 6

Method .......................................................................................................................... 6

Subjects ....................................................................................................................... 6

Test procedure ........................................................................................................... 7

Vertical jump ................................................................................................................ 7

Sprint .............................................................................................................................. 8

Data collection ........................................................................................................... 8

Ethical and social considerations .............................................................................. 9

Statistical analyses .................................................................................................... 9

Result ............................................................................................................................ 10

Correlations between CMJa and 20, 25 meter sprint .............................................. 10

Correlations between DJ and 20, 25 meter sprint ..................................................... 11

Correlations with weight as a control variable ......................................................... 12

Discussion ................................................................................................................... 13

Result discussion ...................................................................................................... 13

Method discussion .................................................................................................... 15

Conclusion .................................................................................................................. 17

References .................................................................................................................. 19

Appendix ...................................................................................................................... 23

Appendix 1. Informed consent ................................................................................... 23

Appendix 2. Test execution ......................................................................................... 25

Appendix 3. Result paper ........................................................................................... 26
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Abstract

Background: Teamgym is a relatively new and emerging sport that originating comes from Scandinavia. Teamgym differs a lot from the most known form of gymnastics, artistic gymnastic. For example artistic gymnastics is an individual sport, while teamgym is performed by 6-12 members in each team. In general gymnasts have to acquire many skills at a very young age like jumping, bouncing and twisting in different directions. A good jumping ability has been linked to a successful performance for gymnasts and is defined by a gymnast’s capacity to jump upwards and then perform series of forward and backward rotations in a successful way. Plyometric is a type of training based on the stretch-shortening cycle (SSC) and is often used to improve an athletes sprint and vertical jump ability. Studies indicate that these two components have been linked to a successful performance in gymnastics but there are no studies that are looking at this correlation in teamgym. Aim: The aim of this study was to investigate how strong the correlation is between the vertical jump height in counter movement jump with arm swing, drop-jump and 20, 25- meters sprint in young female teamgymnasts. Methods: Seventeen (17) female teamgymnasts participated to test their vertical jump ability by using countermovement jump with arm swing (CMJa) and drop-jump (DJ). Their sprint ability was tested through 20 and 25 meter sprint. The highest CMJa and DJ were correlated with the fastest time on 20 and 25 meter sprint. To study the relationship between the vertical jumps and the sprints, Spearman’s rank order correlation ($r_s$) was used in SPSS version 20.0. If the correlation is between 0.30 to 0.49 (-0.30 to -0.49) it is considered as a medium correlation. Anything under these values is a weak correlation and everything above it is strong correlation. Result: CMJa showed a strong significant correlation with both 20 and 25 meter sprint and DJ showed a moderate non-significant correlation with both 20 and 25 meter sprint. When the weight was set as a control variable the CMJa showed a moderate non-significant correlation with both the sprints but DJ showed a strong significant correlation with both 20 and 25 meter sprint. Conclusion: No other studies have looked at the relationship between vertical jump and sprint ability in teamgym but the result of this study somehow reflects findings in studies looking at the same variables. The findings in this study can be useful for gymnastic coaches when they create training programs for their athletes. Coaches and gymnasts will know the value of a good jumping- and sprinting ability and that plyometric- and sprint training can improve the gymnasts skills. More research is needed on this type of gymnastics and future studies should look at these variables in a larger sample size and with more experienced test subjects.
Background

Teamgym is a relatively new and emerging sport that originating comes from Scandinavia. Among all the different gymnastics disciplines, teamgym is the one that attracts the highest number of gymnasts in Sweden, and the interest for the sport is increasing in Europe. Teamgym differs a lot from the most known form of gymnastics, artistic gymnastic. For example is artistic gymnastics an individual sport, while teamgym is performed by 6-12 members in each team (Harringe, Renström & Werner, 2007). The sport includes three different competitive apparatus; tumbling, trampoline and floor routine, performed by 6 to 12 gymnasts at the same time. The floor program is about 3 minutes long and must include different dance steps and acrobatic skills (Minganti, Capranica, Meeusen, Amici & Piacentini, 2010). To get a high score in the floor routine the gymnasts have to work as one and be synchronized. Tumbling and trampoline is performed by 6 gymnasts at the time and includes 3 different tumbles and vault series and it is allowed to change the component of the 6 gymnasts between the series. The total score of the 3 performances of the team will determine which final rank the team gets (Minganti, et al., 2010).

In general gymnasts have to acquire many skills at a very young age like jumping, bouncing and twisting in different directions. A good jumping ability have been linked to a successful performance for gymnasts, especially in the floor routine and when performing vaults, which can be considered as an indicator of gymnastic ability (Marina & Jemni, 2014). The ability to jump is defined by a gymnast’s capacity to jump upwards and then perform series of forward and backward rotations in a successful way (Marina et al., 2014).

Research has shown that if the gymnasts have a high sprint speed it will affect the vertical jump height in a positive way. The gymnast needs a high vertical jump to perform more advanced exercises under the flight time (Bradshaw, 2004). Therefore it is important to introduce the vertical jump to gymnasts in an early age (5-8 years of age) though it is one of the main training aims to acquire. Three different types of vertical jumps can be identified in gymnastics; jumps that occur from a static or semi-static position, jumps that include a previous countermovement motion (associated with the stretch shortening cycle) and jumps that occur after a previous acrobatic exercise (rebound jumps) (Marina & Torrado, 2013).

Before the vault performances (tumbling and trampoline) the gymnasts start from a fixed distance, about 15-25m, and then run towards the take off. Because of the fixed start it is
assumed that the gymnasts stride is consistent between practice, competition and attempts. This means that their feet will land on the same spot on the floor along the run-up (Bradshaw, 2004).

**Physiology of the muscles**

The body’s skeletal muscles are controlled by the central nervous system (CSN) that consists of the brain and spinal cord and the peripheral nervous system (PNS) which consists of nerves that transmit information to and from the CSN (McArdle, Katch & Katch, 2015). The skeletal muscles in our body are organs that contain muscle tissue, connective tissue, nerves and blood vessels. The fibrous connective tissue that surrounds all the skeletal muscles is called epimysium and covers the body’s 430 skeletal muscles. The epimysium connects the muscles with tendons that, in turn, connect with the bone (Baechle & Earle, 2008). Under the epimysium lies the muscle cells which also can be named as muscle fibers and are often very long and shaped as a cylinder. The muscle cells are grouped in bundles and may consist of up to 150 fibers in one group. Each bundle is covered with a surrounded tissue called perimysium and then every muscle cell is covered with a tissue called endomysium. All muscle cells are also covered with a fiber’s membrane called sarcolemma (Baechle & Earle, 2008).

Every muscle cell is innervated by motor neurons that transfer the electrochemical signals from the spinal cord to the skeletal muscles. The motor neuron fires an action potential, also called impulse, which reaches the muscles and cause a reaction. When the impulse reaches the muscle all the connected fibers get activated and start to develop force (Baechle & Earle, 2008). Our muscles can create different amount of force depending on the particular task. This ability is crucial to get a coordinated and smooth movement pattern. The force can be variated in two different ways. Through variation in the frequency at the activation of the motor units, where an increased frequency gives a higher force. The other way is through varying the number of recruited motor units. This process is called recruitment and the more units that is requited the bigger force can the muscle produce (Baechle & Earle, 2008).

In the muscles and tendons in our body we have proprioceptors. These specialized sensory receptors are sensitive to tension, pressure and stretch in our muscles and tendons. The proprioceptors send both voluntary and involuntary signals about muscular and limb movement to the CSN. It is because of them we can feel different body parts position and improve our posture (McArdle et al., 2015). Muscle spindles and Golgi tendon organs (GTOs) are two types of proprioceptors. The muscle spindles, that lie parallel to the muscle cells, provide the CSN with mechanic-sensory information about changes in length and tension in the muscle. They respond to any type of stretch through a reflex response and initiate a stronger muscle action to
protect the muscle. The GTOs can detect differences in the tension generated by an active muscle. The GTOs give feedback under two different conditions: Tension created in the muscle when it gets shortened or when the muscle stretches passively (McArdle et al., 2015).

**Jump and plyometric training**

The ability of a good vertical jump is an important contributor to have a successful performance in many different sports (Marshall & Moran, 2013). Plyometric is a type of training based on the stretch-shortening cycle (SSC) that occurs in our muscles under different exercises like walking, running and jumping (Miller, Herniman, Ricard, Cheatham & Michael, 2006). In these activities the muscle contracts eccentric followed by an immediately concentric contraction. The combination of these two types of muscle work generates a high concentric force and increases the mechanical efficacy because of the storage of elastic energy in the muscles tendons (Malisoux, Francaux, Nielen, Renard, Lebacq & Theisen, 2006). The stored elastic energy can generate more power in the eccentric phase than in the concentric phase, as long as there is no interruption in the movement. Series elastic component (SEC) is a characteristic of tendons, which contributes to the concentric phase under SSC and releases the elastic energy. When the muscles are stretched, for example in an eccentric muscle action, the SEC gets longer. While the SEC is lengthened the elastic energy gets stored in the muscle. If there is no interruption in the movement and the concentric action comes immediately after the eccentric action, the stored energy can be released. The SEC contributes by bringing the muscles and tendons to their normal unstretched configuration (Baechle & Earle, 2008).

The neurophysiological model of plyometric involves potentiation in the muscles when they work concentric which cause a stretch reflex. This stretch reflex is an involuntary response from the body when an external stimuli causes the muscles to stretch out. The reflex is caused by muscle spindles that are sensitive to the magnitude of a stretch. When the stretch occurs quickly, like in plyometric exercises, the muscle spindles get stimulated and cause a reflexive muscle action. If the muscle action and the load gets too high, the GTOs acts as a security mechanism to protect the muscles and tendons from rupture and damage (Baechle & Earle, 2008).

As mentioned vertical jump is a common movement in many different sports. A popular vertical jump is the countermovement jump (CMJ). This vertical jump involves a preparatory phase when the athlete sinks downwards before an extension of the hip, knee and ankle appears and the athlete pushes upward. Another vertical jump that is similar to the CMJ is the squat jump (SJ). The SJ starts from a semi-squatted position and without any help from the SSC the athlete
extend the hip, knees and ankles and pushes upwards (Bobbert, Gerritsen, Litjens, & Van Soest, 1996). It has been shown that athletes can produce more work and use the produced work more effectively when performing a CMJ in comparison with the SJ (Anderson & Pandy, 1993). To enhance an athlete’s maximum CMJ height many coaches use a so called drop-jump (DJ). The DJ involves stepping from a height and when the feet hit the ground, jumping vertically as high and explosive as possible. DJ provides a larger amount of eccentric loading than the CMJ which effective’s utilisation of the SSC, and in turn a greater force production in the concentric phase of the jump (Moran & Wallace, 2007).

Marina et al. (2013) studied the hypothesis that gymnasts who practising jump from a young age would have a higher reliability in three different vertical jumps (SJ, CMJa and DJ) compared to a control group of people with other training background. At an age of 8-10, which is an introductory gymnastic level, being a gymnast did not lead to a higher vertical jump reliability but they had a better vertical jump ability in SJ, CMJa and DJ overall than the control group. These findings can be based on the learning process of jumping, if a gymnast train on a specific jump he/she will be able to jump higher in that specific jump.

Plyometric training does not only improve vertical jump, it also improves acceleration in sprinting and running as well as increases the athlete’s strength in the lower extremity (Miller et al., 2006).

**Sprint**

A sprint consists of three different subtasks: initial starting phase, acceleration phase and maximum running phase. Both muscle action in the lower extremities, power and force differs in the three different subtasks because of the change in the lean of the body (Markovic, Jukic, Milanovic, & Metikos, 2007).

In the initial phase the athlete gets its acceleration mostly by using concentric force production from the knee and hip extensor muscles. It is crucial for the athlete to produce this high concentric force in the initial phase to be available to produce a high velocity during the sprint. In the maximum running phase the speed is determined mainly of the hip and ankle extensors action. This means that in the maximum running phase the SSC action, in particularly the ankle extensors, is very important (Markovic et al., 2007).

The acceleration and maximum running phase can be divided in to two different types of foot work: flight phase and support phase. The flight phase contains of recovery and ground preparation and the support phase includes eccentric decelerating and concentric force (Baechle
A successful sprinter needs to have a good starting ability, a high maximum running velocity and a good endurance ability (Kale, Asci, Bayrak, & Acikada, 2009). It is also important to have a high stride frequency and an optimal stride length for the athlete to improve their sprinting ability. An athlete’s stride length is related to the height of the body and leg length which makes it unique for each individual. The stride frequency also has a variation but is more trainable than the stride length (Baechle & Earle, 2008). The highest sprinting speeds are reached at its best at 30 to 60 meters sprint (Kale et al., 2009).

In sprint the muscles in your body have two vital functions; accelerate the body and keep it in a horizontal position and work against the vertical directional force of gravity. These tasks can only be achieved when the athlete has contact with the ground and is not affected by the duration of muscle activity (Wiemann & Tidow, 1995).

The muscles that play the most important role when it comes to acceleration and horizontal velocity in full sprinting are the gluteus maximus, adductor magnus, hamstrings (semitendinosus, semimembranosus and biceps femoris) and the knee extensors. Hamstrings are active during the whole back swing and support phase (the phase of hip extension) while gluteus maximus and the knee extensors only are active during the back swing phase and in the beginning of the support phase. Adductor magnus stops to be active already at the beginning of the support phase. When hamstrings, gluteus maximus and adductor magnus work together they provide the body with needed energy to create forward propulsion (Wiemann et al., 1995).

A good technique in sprinting plays an important role, since the athlete cannot reach its maximum speed without it. Incorrect technique can be associated with fatigue, coordinative/physical abilities or improper coaching (Baechle & Earle, 2008).

**Associations between vertical jump and sprint**

A study conducted by Vescovi and Mcguigan (2008) looked at the relationship between sprinting, agility and jump ability in female athletes. Altogether, 83 high school soccer, 51 college soccer, and 79 college lacrosse athletes took part in the study. They looked at four different sprint distances between 9 and 37 meter and correlated the sprint time with the height of CMJ. They found a stronger correlation between the two longer sprint distances and the height in CMJ than in the shorter sprint distances and the correlation was stronger among the college athletes than the high school athletes.

Another study examined the relationship between speed, agility and vertical jump ability in young soccer players where the average age was 16.0 ± 0.8 years. The speed ability was
assessed by a 10 and 30 meter sprint test and the vertical jump ability through SJ and CMJ test. They found low correlations between the height in SJ and CMJ and the 10 meter sprint (0.030 and -0.123) and moderate correlations between SJ and CMJ height and the 30 meter sprint (-0.367 and -0.599) (Köklü, Alemdaroğlu, Özkan, Koz & Ersoz, 2015).

Carr, McMahon and Comfort (2015) looked at the relationship between jump height and 5, 10 and 20 meter sprint in first-class county cricketers. They found a strong, significant relationship between CMJ height and all of the sprints, where the CMJ and the 20 meter sprint time had the strongest correlation ($r = -0.741$, $p = 0.006$, $r^2 = 0.555$)

Chelly, Ghenem, Abid, Hermassi, Tabka & Shephard (2010) found that an 8-week in-season biweekly plyometric training program improved both the acceleration phase (0-5 meter), maximum speed phase (0-40 meter) and jumping ability in SJ and CMJ in male regional junior soccer players.

Bradshaw (2004); Bradshaw and Rossignol (2004) have written about how important a good vertical jump and sprinting ability is for gymnasts but there are no studies that looking at this correlation in teamgym. Therefore the aim of this study is to see if there is a relationship between vertical jump height and sprint ability in young female teamgymnasts.

**Aim**
The aim of this study was to investigate how strong the correlation is between the vertical jump height in countermovement jump with arm swing, drop-jump and 20, 25- meters sprint in young female teamgymnasts.

**Method**
In this study eighteen female teamgymnasts were recruited to test their vertical jump ability by using countermovement jump with arm swing (CMJa) and drop-jump (DJ). Their sprint ability was tested through 20 and 25 meter sprint. Due to sickness one subject had to withdraw from the study, which means that the final amount of test subjects was seventeen. The result of the vertical jumps was correlated with their time on 20 and 25-meter sprint.

**Subjects**
Female teamgymnasts from a local gymnastics club were recruited for the study. The inclusion criteria to participate were that the subjects had to be healthy, injury-free by the time the test was taken and been active in the sport teamgym for at least three years. Seventeen subjects, aged 12-17, participated in the study. If a subject got an injury that could affect the result, or
got sick, she was not allowed to complete the study. The subjects had to report their weight, length and age before the test started (table 1).

Table 1. Table that shows the test subjects (N=17) weight, length and age, given in median, minimum and maximum value.

<table>
<thead>
<tr>
<th></th>
<th>Weight (kg)</th>
<th>Length (cm)</th>
<th>Age (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>50</td>
<td>162</td>
<td>13</td>
</tr>
<tr>
<td>Minimum</td>
<td>39</td>
<td>155</td>
<td>12</td>
</tr>
<tr>
<td>Maximum</td>
<td>65</td>
<td>173</td>
<td>17</td>
</tr>
</tbody>
</table>

Test procedure
A week before the first test opportunity the subjects participated in a familiarization trial where they were informed about the tests they were going to perform. The familiarization trial and the tests took place at “Gymnastikens hus” in Halmstad and the tests were separated in two opportunities. Both the familiarization trial and the test took place at the gymnast’s normal training session in the late afternoon. At the first session the subjects were split in two groups, one group performed the DJ and CMJa test and the other one the sprint test. A week later the group switched, meaning that the half that performed the vertical jumps performed the sprint test and the other half the DJ and CMJa test. Three test leaders were present at the tests. Test leader 1 and 2 were in charge of the vertical jump test and test leader 3 of the sprint test.

After the introduction the subject performed a standardized warm-up for about 10-15 minutes, which was the same for both test occasions. The warm-up included jogging, shuffling, sprinting and dynamic stretch (Vescovi et al., 2008).

Vertical jump
The subjects performed two different vertical jumps, DJ and CMJa. Before the test the subjects performed two test rounds of each jump as a part of the warm-up (Habibi, Shabani, Rahimi, Fatemi, Najafi, Analoei & Hosseini, 2010). All the jumps were performed without shoes to simulate the gymnast’s normal training and competing condition (Marina, Jemni, Rodriguez, Jimenez, 2012). After the two test rounds each subject performed three trials of each jump that was recorded. At both the DJ and CMJa the test subjects had to have their face against one of the sensors. The highest jump of the three trials was analyzed in the study (Markovic et al., 2007).

The CMJa was standardized with a knee angle of 90 degrees and controlled by one of the test leaders. The subjects were informed to go down to 90 degrees and then directly after a signal
from the test leader push upwards into a vertical jump (Romero-Franco & Jiménez-Reyes, 2015). The subjects were instructed to use their arms during the jump to get more height. The DJ was performed from a 33cm high box and the subjects was instructed to step out as vertical as possible (Markovic et al., 2007). They were also instructed to minimize the ground contact and jump as high as possible (Marina et al., 2012). While performing the DJ the subjects had to have their hands placed on their hip through the entire jump.

The rest between each jump was set at one minute (Markovic, Dizdar, Jukic & Cardinale, 2004) and between the different jump types the subjects had to rest at least 6 minutes to get rid of fatigue (Vescovi et al., 2008). Verbal encouragement was given at both the vertical jumps and the sprint test.

**Sprint**

The sprint was performed without shoes (Marina et al., 2012) on a thin mat which is used in the trampoline event. The subjects are used to run without shoes so this made the test more sport specific. After the warm up the subjects had two test rounds of the sprint before the three recorded trials started (Habibi et al., 2010). The subjects started the sprint with their optional front foot on a mark set on the ground. The mark was set 0.5 meters before the starting line to avoid that the subjects were crossing the sensors before the test started (Carr et al., 2015). They were informed to run as fast as possibly throughout the finish line and they started on their own signal. Between the three sprint trials the subjects rested at least 3 minutes (Vescovi et al., 2008). The fastest time of the three trials was collected to be analyze in the study (Markovic et al., 2007).

**Data collection**

To collect data from both the sprint and jump test, the IVAR test system (Mora, Sweden) was used. The sensors that were used at the jump test were positioned 1.5 meters away from each other according to the recommendations for the equipment. The placement was marked with tape on the floor to be sure that the sensors did not move during the test.

The sensors that were used during the sprint test was placed 1.5 meters away from each other along the 25 meter long sprint distance. The sensors were positioned at 0, 20 and 25 meters and the placement was marked with tape to be sure that the sensors did not move during the test. The height of the sensors was set at 1.05 meters above the ground. Both the placement and the height of the sprint sensors were according to the recommendations for the equipment.
Ethical and social considerations
The subjects were given both oral and written information by the test leaders and had to sign an informed consent (appendix 1). All the subjects were under 18 years old so a guardian had to sign the consent and approve their participation in the study. The subject were informed that they could, whenever they wanted, withdraw from the study without giving a reason. None of the collected data or names of the subjects can be identified and the test leaders had the responsibility for the subjects during the test opportunities. The subjects were not exposed to any danger as all of them had at least 3 years’ experience of the sport teamgym and were used to sprint and jump as it is a big part of their regular training.

The study only included young female teamgymnasts which makes the result more reliable for this type of group. This also means that the result will not be applicable on any other study where both the sexes are represented.

The results of this study could be useful for gymnastic coaches when they create training programs for their athletes. Coaches and gymnasts will know the value of a good jumping- and sprinting ability and how the SSC works.

Statistical analyses
To see if the data was normally distributed, the Shapiro-Wilk test was used. The test showed that 2 out of 4 parameters had a p-value <0.05 (p<0.001) which indicate that nonparametric statistic should be used. The low number of test subjects in this study are also a factor that plays a role when you choose nonparametric statistics (Cohen, 1988).

To study the correlation between CMJa, DJ and the sprint time at 20 and 25 meter, Spearman’s rank order correlation ($r_s$) (Bivariat Correlation Spearman, two tailed) was used in SPSS version 20.0 (IBM,USA). The highest result of CMJa and DJ was correlated with the fastest sprint time at 20 and 25 meter (Markovic et al., 2007). A partial correlation was used to see if the test subject’s weight would affect the correlation value.

A correlation can have a range of -1.00 and 1.00 and indicates how strong the relationship between two different variables is. A perfect negative correlation will be -1.00 and a perfect positive correlation 1.00. To interpret the values between 0 and 1 this study used following guidelines: If the correlation is between 0.30 and 0.49 (-0.30 and -0.49) it was considered as a moderate correlation. Anything under these values was a weak correlation and everything above it was a strong correlation (Cohen, 1988). By using the coefficient of determination ($r^2$) you can interpret how much variance the two variables share in the correlation. $R^2$ indicates the level of
shared association factors which influence the two tested variables. To get the coefficient of determination you multiply your correlation coefficient by itself and to convert it to percent you multiply your answer with 100 (Cohen, 1988).

**Result**

Seventeen young team gymnasts participated in the study and got their results analyzed. Their vertical jump ability were tested through countermovement jump with arm swing (CMJa) and drop-jump (DJ) and their sprint ability through 20 and 25 meter sprint. The highest values of CMJa and DJ were correlated with the fastest sprint time in 20 and 25 meter sprint.

The result of the test subjects jump height in CMJa and DJ, 20 and 25 meter sprint times are shown in table 2.

Table 2. Table that shows the test subjects (N=17) test result, given in median, minimum and maximum value.

<table>
<thead>
<tr>
<th></th>
<th>CMJa (cm)</th>
<th>DJ (cm)</th>
<th>20 meter sprint (sec)</th>
<th>25 meter sprint (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>36.00</td>
<td>28.50</td>
<td>3.33</td>
<td>4.01</td>
</tr>
<tr>
<td>Minimum</td>
<td>29.00</td>
<td>18.10</td>
<td>2.11</td>
<td>2.56</td>
</tr>
<tr>
<td>Maximum</td>
<td>47.30</td>
<td>39.30</td>
<td>3.49</td>
<td>4.23</td>
</tr>
</tbody>
</table>

**Correlations between CMJa and 20, 25 meter sprint**

CMJa showed a strong negative correlation with 20 meter sprint, $r_s=-0.505$, $r^2=0.255$ ($p=0.039$), figure 1. The CMJa also showed a strong negative correlation with 25 meter sprint, $r_s=-0.526$, $r^2=0.277$ ($p=0.030$), figure 2.
Fig. 1. Correlation between countermovement jump with arm swing (CMJa) and 20 meter sprint ($r_s = -0.505$)

Fig. 2. Correlation between countermovement jump with arm swing (CMJa) and 25 meter sprint ($r_s = -0.526$)

**Correlations between DJ and 20, 25 meter sprint**

DJ showed a moderate negative correlation with 20 meter sprint, $r_s = -0.366$, $r^2 = 0.134$ (p = 0.148), figure 3. Compared to 25 meter sprint, DJ also showed a moderate negative correlation, $r_s = -0.368$, $r^2 = 0.135$ (p = 0.147), figure 4.
Correlations with weight as a control variable

When the weight was set as a control variable in the partial correlation, the correlation coefficient between CMJa and 20 meter sprint was $r_s = -0.430$ and $p = 0.096$. Between CMJa and 25 meter it was $r_s = -0.471$ and $p = 0.066$. 

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**Fig. 3.** Correlation between drop-jump (DJ) and 20 meter sprint ($r_s = -0.366$) 

**Fig. 4.** Correlation between drop-jump (DJ) and 25 meter sprint ($r_s = -0.368$)
The correlation coefficient between DJ and 20 meter sprint was $r_s = -0.668$ $p = 0.005$. Between DJ and 25 meter sprint it was $r_s = -0.671$ $p = 0.004$. This means that when the weight was used as a control variable for the DJ and sprint, there was a significant relationship between the height of DJ and 20, 25 meter sprint.

**Discussion**

In this study seventeen young female teamgymnasts vertical jump ability was tested in CMJa and DJ. Their sprint ability was tested through 20 and 25 meter sprint. The highest value of the CMJa and DJ was correlated with the fastest sprint time on 20 and 25 meter sprint. The result of this study showed a strong significant correlation between CMJa and 20, 25 meter sprint. The DJ showed a moderate non-significant correlation between 20, 25 meter sprint. When the weight was set as a control variable the DJ showed a strong significant correlation with both the 20 and 25 meter sprint.

**Result discussion**

This study investigated the relationship between vertical jumping ability and sprint in young female teamgymnasts. Kale et al. (2009) looked at the relationship between SJ, CMJ, DJ and the maximum speed phase during 100 meter sprint. They found moderate significant correlations between SJ ($r_s = 0.56$), CMJ ($r_s = 0.55$) and the maximum speed phase and strong significant correlations between DJ ($r_s = 0.69$) and the maximum speed phase. The study by Kale et al. (2009) differs somewhat from the results in this study. They got a stronger correlation (>0.6) with the DJ than the CMJ which was contrary to the result in this study where the CMJa had a higher correlation with the sprint. Worth mentioning is that the CMJ in this study was performed with arm swing unlike Kale et al. (2009) where the subjects had their hands placed on the hip. This could have caused a higher vertical jump in CMJa in this study compared to the DJ.

Carr et al. (2015) found a moderate (0.4-0.6) non-significant correlation between DDJ (depth drop jump) and 20 meter sprint and a strong (>0.7) significant correlation between CMJ and 20 meter sprint. The result from Carr et al. (2015) reflects this study’s result, they also got a higher correlation between CMJ and 20 meter sprint than DDJ and 20 meter sprint.

Differences between these two studies and this one are that they both used male test subjects with a mean age of 20.4 and 23.8 years (present study 13 years) and they were also active in other sports, sprinting and cricket. They also followed other guidelines regarding the strength of the correlation. In this study the correlation would be strong if the correlation coefficient
were >0.5 but for example Carr et al. (2015) wrote that the correlation were strong if it had a correlation coefficient >0.7. The difference in the result between these three studies could have been affected by the subjects training background, age but also current training status.

Maximal sprint speed is reached by an optimal stride length and stride frequency together with a good muscle strength and is best reached at 30 to 60 meter (Kale et al., 2009). In this study the subjects ran 25 meter sprint with a split time at 20 meter. A 25 meter sprint was chosen because it reflects their training and competition condition as they run this distance in the trampette event (Gymnastikförbundet, 2016). It is possible that the subject would have reached a higher sprint speed if the distance was longer. It is not sure that all test subjects had reached their maximal sprint speed at 25 meter as it varies for each individual. A longer sprint distance would, however, put higher demands on a greater muscle strength in the lower extremity. As optimal stride length and stride frequency is necessary to reach maximal sprint speed the subjects running technique could have affected the result as well. It is possible that higher sprint speed on 20 and 25 meters would have been reached if the subjects trained more running and sprint technique.

Both the sprint and the jumps that were tested in this study uses the SSC which the subjects are used to from their training as they often perform similar kinds of vertical jumps and short sprints. In this study CMJa got a stronger correlation with 20 and 25 meter sprint than DJ. The CMJa were performed with arm swing as they are used to in their normal training. This may have affected the results and led to a higher vertical jump height in CMJa compared to DJ.

All of the correlations in this study showed a quite low coefficient of determination ($r^2$), where the highest was between CMJa and 25 meter sprint ($r^2=0.277$). This means that approximately 28% of the sprint result on 25 meter sprint can be explained by the vertical jump height in CMJa. The lowest coefficient of determination was found between DJ and 20 meter sprint, $r^2=0.134$ which means that approximately 13% of the sprint result on 20 meter sprint could be explained by the vertical jump height in DJ. Things that could have affected the low $r^2$ value are a bad running technique, the subjects training status and the study’s set-up and design.

The weight was set as a control variable in all the correlations. The weight contributes to the total load that the subjects have to accelerate in different dynamic athletic movements such as jump and sprint (Cormie, McBride & McCaulley, 2007).
Another anthropometric fact that could have affected the jump height is the length of the subjects. The reason why weight was chosen instead of length was because the length only affect the jump indirect. A tall person often weight more than a short one but it is still the weight that affects the movement and not the fact that the person is tall. When the weight was set as an control variable to the correlations between DJ and 20, 25 meter sprint there was a strong ($r_s >0.5$) significant ($p= <0.05$) relationship between DJ and 20, 25 meter sprint. This change of strength in correlation and significance indicates that the weight of the subjects affected the DJ more than CMJa. DJ is performed by stepping as vertical as possible from a box, land with both feet on the ground and then push directly upwards into a vertical jump. The subjects had to absorb the force from their own body weight before they pushed away from the floor in opposite direction. In a CMJa jump the test subject’s feet is already placed on the ground and this cause less impact on the jump height. This may explain why the DJ had a higher correlation when the weight was set as a control variable.

**Method discussion**

Teamgymnasts were chosen because a good vertical jump and sprint ability are two important components in their training (Bradshaw, 2004) but also because no similar studies have been done on this kind of gymnastics. The age of the subjects was between 12-17 years which is a relative large age range. The original thought was to have test subjects in the same age of 14-15 years but because there was no gymnastic team with this age range the recruitment fell on a gymnastic team with a wider age range. It was more valuable to include a larger number of subjects than have a homogenous group. Although the age range was 12-17 years the median age was 13 years which means that there were more subjects close to the minimum (12 years) than the maximum age (17 years).

The number of test subjects in this study was seventeen which is a pretty low number. This is a factor that could have affected both the strength of the correlation and its significant level. Cohen (1988) write that a low number of subjects strongly affects the significant level. For example in small sample you could have a moderate correlation which does not reach the significance level of $p<0.05$ while in a big sample you could have a small correlation that is significant. In this study the correlation coefficient between CMJa and 20, 25 meter sprint were rated as a strong correlation with a significant relationship. Between DJ and 20, 25 meter sprint it was rated as a moderate correlation with a non-significant relationship. Thomas, Nelson & Silverman (2011) write that a low number of test subjects requires a strong correlation to get a
significant relationship. So was the case in this study were the CMJa got a strong correlation with 20, 25 meter sprint and a significant relationship between the jump and both of the sprints. If the number of test subjects was bigger, the DJ and 20, 25 meter sprint could have got a significant relationship.

The warm up were designed to imitate the one Vescovi et al. (2008) did in their study and included 10-15 minutes of jogging, shuffling, sprinting and dynamic stretch. Baechle and Earle (2008) recommend dynamic stretching in front of static stretching in a warm up to avoid any negative effects on force production, power performance and running speed. This indicates that the choice of stretch during warm up in this study likely has not affected the subject’s vertical jump and sprint ability.

CMJa and DJ were chosen because they are similar to the test subject’s normal movement patterns in training and competition. The DJ was performed without any help from the arms to differ from the CMJa because both of these vertical jumps include a previous countermovement motion which is associated with the SSC (Marina et al., 2013).

During the vertical jump test, all test subjects performed same order of the jumps, first CMJa and then DJ. It would have been interesting to see if a randomization of the jumps would affect the vertical jump height especially in the DJ as it was performed after the CMJa. Since only 3 repetitions of each jump were performed, the vertical jump height in DJ hopefully was not affected by any tiredness from the test subjects.

During both the jump- and sprint test the IVAR test system was used. At the jump test the system recorded how long the athlete was in the air and from that calculated the jump height. In a study were they measured reliability and validity of the IVAR system in SJ, CMJ and compared three different methods for estimation of vertical jump height, they found that vertical jump height gives most reliable and valid results with an equipment that controls the athletes time in the air (Markovic et al., 2004).

At the sprint test the subjects performed the sprint barefoot on a thin mat which is used on the trampette event. Teamgymnast trains and competes barefoot so this made the test more sport specific. Although it is more sport specific, the fact that the subjects run barefoot and on a thin mat could have affected their sprint result. The thickness of the mat has to be 2.5 cm +/- 0.5 cm (Gymnastikförbundet, 2016) which means that the gymnast’s feet sink in a little bit in the mat. This could have caused a more slowly sprint time for the subjects than if they would have run on a floor. Running shoes could have given the subjects a better grip to the floor and thereby
improved their times on 20 and 25 meter sprint but not the correlation between vertical jump height and sprint.

At the sprint test the surface after the 25 meter sprint distance were covered by a thick and soft mat which was placed about one meter from the sprint distance. The mat could be raised and lowered so it matched the floor level. This meant that the surface after the sprint changed rapidly for the test subjects. To avoid this a harder mat was placed over the original mat so the subjects would not feel uncomfortable. The surface of the stopping distance was still not as hard as the actual sprint distance. The subjects were asked if they could run as fast as possible throughout the whole sprint which they said they could. Despite this, the change in surface after the sprint could have affected the subject’s ability to run as fast as possible throughout the finish line.

The subjects performed one sprint at 25 meter with sensors positioned at 0, 20 and 25 meter. From this 25 meter sprint the time at 20 meter also was collected to the analysis. The reason why 20 and 25 meter were chosen was because teamgymnasts run between 15-25 meter before they perform the tumbling and trampoline event. The distances were also chosen because of collaboration with another student who looked at shorter distances. Another method to collect the data from the sprint test would have been to let the subjects do two different sprints, one at 20 meters and one at 25 meters. Due to lack of time and collaboration with another student during the data collection, one sprint of 25 meter was chosen with a split time at 20 meter. This method also reflects how other studies have performed their sprint test. In previous studies done by Köklü et al. (2015) and Carr et al. (2015), they collected two sprint times in one sprint. Köklü et al. (2015) for example performed a 30 meter sprint where they collected the time from 10 meter as well and then used it in their correlations.

**Conclusion**

This study showed a strong significant correlation between CMJa height and 20,25 meter sprint. DJ showed a moderate non-significant correlation with both 20 and 25 meter sprint. When the weight was set as a control variable the DJ went to a strong significant relationship with both 20 and 25 meter sprint. No other studies have looked at the relationship between vertical jump and sprint ability in teamgym but the result of this study somewhat reflects findings in studies looking at the same variables. The findings in this study can be useful for gymnastic coaches when they create training programs for their athletes. Coaches and gymnasts will know the value of a good jumping- and sprinting ability and that plyometric- and sprint training can improve the gymnasts skills. More research is needed on this type of gymnastics and future
studies should look at these variables in a larger sample size and with more experienced test subjects.
References


Appendix

Appendix 1. Informed consent

Information till deltagare.

Hej!

Deltagande
Du tillfrågas då att du träna truppgymnastik i föreningen Halmstad Frigymnaster. För att delta i studien krävs det att du har varit aktiv inom sporten i minst 3 år och fortfarande är aktiv, samt att du är skadefri och fri från sjukdomar som kan påverka testernas resultat. För medverkande under 18 år måste målsman ge sitt medgivande till deltagande i studien.

Tillvägagångssätt

Frivilligt deltagande
Du som testperson har rätt att avbryta testet när som helst utan att ange orsak. Om så önskas kommer då redan insamlad data att förstöras. Innan första testtillfället kommer du skriva på detta samtycke och lämna in det påskrivet på plats. År du under 18 år behöver även en målsman skriva under. Vi som testledare har ansvare för testpersonerna under testtillfällena samt samlar data som samlas in.

Sekretess
Information om deltagare kommer hanteras konfIDENTiellt. Ingen personlig information kan utläsas varken i den skriftliga upplagan eller vid redovisning av studien. Om så önskas, finns möjlighet att ta del av sitt personliga testresultat. Har du några frågor eller önskar mer information så är du välkommen att kontakta oss, Hannah Svensson och Emma Larsson enligt kontaktuppgifterna nedan.

Vänliga hälsningar,
Hannah & Emma
**Ansvariga**

Hannah Svensson  
Biomedicin – inriktning fysisk träning, Högskolan i Halmstad  
0703895052  
**hansve13@student.hh.se**

Emma Larsson  
Biomedicin – inriktning fysisk träning, Högskolan i Halmstad  
0708601895  
**emmlar13@student.hh.se**

**Handledare:**  
Maria Andersson  
**Maria.Andersson@spenshult.se**

Jag har tagit del av informationen och ställer upp som testperson:

Namn:_____________________________________
Datum/Ort:__________________________

Målsmans 
underskrift:____________________________________________________________
Appendix 2. Test execution

Vertikalhopp och sprint, tillvägagångssätt

Checklista:
– Sprintutrustning
– Hopputrustning
– Måttband
– Tejp (vit och svart)
– Förlängningssladd x2
– Resultatpapper
– Pennor
– Tidtaggar

Regler sprint utrustning:
– Mät ut 25 meter, markera med tejp
– Sensorer ska vara placerade på 0, 10, 15, 20, 25 meter
– Mät ut 1,5 meter mellan sensorerna, markera med tejp
– Samma höjd på alla sensorerna! Ca 1,05 meter
– Mät upp 0,5 meter från startlinjen, markera med tejp

Regler sprint utförande:
– En fot vid startlinjen (0,5 meter)
– Stillastående start utan gungning
– Testa sprintsträckan 2 gånger
– 3 försök på sprinten, vila minst 3 minuter mellan försöken
– Skriv resultat på tillhörande papper för varje testperson
– Heja gärna på!

Regler hopp utrustning:
– Placera sensorerna 1,5 meter ifrån varandra, markera med tejp!
– Koppla in sladdar korrekt
– Vid fel kolla batteri, sladdar, golvet mellan sensorerna och smuts
– Ställ in på 10 millisekunder
– Ställ in på 1 hopp

Regler hopp utförande:
– Testa hoppen 2 gånger
– Ansiktet vänd emot en sensor (valfri)
– 3 försök på varje hopp, vila minst 1 minut mellan försöken, vid byte av hopp 6 min!
– Om ett hopp ej blir godkänt räknas det bort och ett nytt försök får göras direkt
– Heja gärna på!

CMJa (armsving)
Höftbrett, sjunk ned till 90 grader, få ett ok och trycka ifrån rakt upp med raka ben. Hoppet ska ske i en rörelse, ej stanna i botten!

Squat jump (händerna på höften)
Höftbrett, sjunk ned till 90 grader, testledare räknar till 3 och tryck ifrån rakt upp

Drop-jump (händerna på höften)
Steg ut med en fot så vertikalt som möjligt, landa jämfota och sedan så snabbt som möjligt tryck ifrån rakt upp. (Instr. ”Så lite kontakt med golvet som de går och hoppa så högt ni kan”
Appendix 3. Result paper
Tester vertikalhopp & sprint

Testperson:_______________________________________________________
Vikt:______________ Längd:______________ Ålder:______________

Hopp datum: ___________ Testledare:______________________________
CMJa
1:__________________
2:__________________
3:__________________
Squat jump
1:__________________
2:__________________
3:__________________
Drop- jump
1:__________________
2:__________________
3:__________________

Sprint datum: ___________ Testledare:______________________________

<table>
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<th></th>
<th>0-10 meter (split 0-10)</th>
<th>0-15 meter (split 10-15)</th>
<th>0-20 meter (split 15-20)</th>
<th>0-25 meter (split 20-25)</th>
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