Relative Age Effects among Physically Active Adolescents

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Acknowledgments

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Abstract

**Background:** Studies have shown that children and adolescents who are relatively older than their younger peers have advantages in sports, partly because they are more biologically mature, a relative age effect (RAE). However the occurrence of RAE in physical performance is still somewhat unclear and more knowledge is needed. **Aim:** The aim of this study was to investigate if there were any RAEs on anthropometric measures and physical performance in adolescents who are 13 years old and active in sports. **Methods:** 128 subjects (78 boys, 50 girls) from Malmö idrottsakademi, a school with a sports profile, were included in this study. Measurements of height and weight were taken and the physical performance was tested for grip strength, sprint and countermovement jump (CMJ). To analyse RAEs the subjects were divided into three groups (teriles) according to their month of birth. Subjects born in Tertile 1 (Jan-Apr) and Tertile 3 (Sep-Dec) were compared together as well as within and between the sexes with independent t-tests. **Results:** RAEs were present in height (p=0.01), weight (p=0.01), and grip strength (0.03) where higher values were found in the relatively older subjects. Additionally, if weight was accounted for, RAE was present in CMJ where the relatively younger subjects performed better (p=0.03). Further, when sexes was analysed separately the older boys were taller (p=0.01), heavier (p=0.02), and stronger (p=0.05) compared with the younger boys. The older girls were heavier (p=0.01) compared with the younger girls whereas the younger girls got a higher CMJ weight ratio (p=0.05). **Conclusion:** RAEs were found on anthropometric measures, but were less clear in physical performance. This indicates that although relatively older adolescents are taller and heavier, they are not always in advantage over their younger peers regarding physical performance.
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Background

Relative age effect
Children and adolescents are often grouped according to their chronological age in sports. In Europe a common cut-off date is 1 January which means that the participants in a sports team are born between 1 January and 31 December of the same year. Further this means that there might be a difference of almost as much as 12 months between the oldest and the youngest child in the team (Gil et al., 2014). This phenomenon is known as relative age while the consequence of it is called relative age effect (RAE) (Gutierrez Diaz Del Campo, Pastor Vicedo, Gonzalez Villora & Contreras Jordan, 2010). Barnsley, Thompson and Barnsley (1985) were one of the first to identify RAE in their study of ice hockey players. They found a biased distribution in birth dates among National Hockey League players where almost twice as many were born in the first quarter (1Q) of the year, i.e. from 1 January to 31 March, than in 4Q, i.e. from 1 October to 31 December. The study also included two amateur junior leagues where approximately four times more players were born in 1Q than in 4Q (Barnsley et al., 1985).

Although this kind of classification is made to facilitate fair competition for the participants, it may yet imply some differences within a group. An example of difference is variations in maturity where those who are born shortly after the cut-off date may be more physically developed than those born later and thus the relatively older are in advantage (Cobley, Abraham & Baker, 2008). RAЕs can also be expressed as differences in psychosocial development and experience of sports to the benefit of the older ones (Wattie, Cobley & Baker, 2008).

Assessing maturity
As mentioned earlier there can be a great variance in level of biological maturity among adolescents of the same chronological age, especially during growth spurt (Sherar, Baxter-Jones, Faulkner & Russell, 2007). Although the level of maturity can vary considerably, older subjects are yet more likely to enter maturity before their younger peers, hence the RAE in maturity (Jiménez & Pain, 2008). The best method to assess maturity is to measure skeletal age since maturation of the skeleton covers the entire period of growth. However the measurement is expensive and exposes the subject to radiation, and therefore other methods are often used instead. One of the most commonly used indicators of maturity status is age at
peak height velocity (PHV) which is when the rate of growth in height is fastest. The growth of leg length occurs before the growth of sitting height, and the knowledge of this difference in timing of growth is used to estimate PHV (Mirwald, Baxter-Jones, Bailey & Beunen, 2002). PHV occurs on average at 12 years of age in girls and at 14 years of age in boys and the standard deviation is about 1 year, and PHV is somewhat less intense in girls (Malina, Bouchard & Bar-Or, 2004). Both anthropometrics and physical performance are influenced by maturation and thereby PHV too (Philippaerts et al., 2006).

**Biological maturity and strength development**

Running and jumping are movements that occur in the vast majority of sports, and strength is an important determinant to execute these powerful movements (National Strength & Conditioning Association, 2008). National Strength & Conditioning Association (2008) expressed strength as “the ability to exert force” (p. 73) which is influenced by the cross-sectional area of a muscle. Another determinant is the recruitment of motor units, regarding both the number of motor units involved as well as their firing rate (National Strength & Conditioning Association, 2008). A muscle contraction is initiated by an action potential by a motor neuron which leads to several chemical reactions within the muscle fibre. As a consequence of that a movement of the contractile proteins actin and myosin in the muscle fibres occurs and thereby a contraction of the whole muscle. Some nerve fibres are wrapped with myelin sheaths which enable faster transmissions of nerve impulses to muscles. However, myelination of motor nerves is not fully developed until full maturity is reached and this has effects on performance of different skills. This manifests itself in impairments in reaction as well as strength and power requiring tasks, but the performance in these tasks improves as the myelination is complete (McArdle, Katch & Katch, 2015).

As children grow there is a consistent increment of strength and muscle mass, but during puberty this increment is much more distinct, especially in boys. This large growth spurt in muscle mass in adolescent males is a consequence of the increased production of testosterone which in turn leads to higher concentration of growth hormone. The same amount of increment does not occur in girls because of hormonal differences (Malina et al., 2004).

The increment in muscle mass during adolescence is a result of hypertrophy and not hyperplasia, and this is common to both sexes (National Strength & Conditioning Association, 2008). Hypertrophy is a result of an increment in the size of the existing muscle fibres while hyperplasia refers to an increment of the number of muscle fibres (McArdle et al.,
Muscular strength is an effect of the increment in muscle mass, and during periods of rapid growth an increment in muscle mass is seen before an increased ability to exert strength. Since there is a stronger relationship between physiological functions and biological age compared to chronological age, it is likely that adolescents who are more maturated have advantages in strength compared to less matured peers (National Strength & Conditioning Association, 2008).

**Differences between sexes in performance development**

Physical performance is affected by growth as well as maturity, thus PHV serves as a landmark for physical performance. For example, peak development of strength occurs after PHV in both boys and girls while development of running speed peaks before PHV. Up to 13 to 14 years of age a linearly increase in strength is seen in boys which is followed by an acceleration in strength development, but as previous mentioned this strength spurt is not that apparent in girls. Sex differences are also seen in running speed where performance improves up to 13 to 14 years of age in girls whereas improvements in boys are seen until 18 years of age. Generally the performance between boys and girls do not differ in early adolescence, but as they develop into puberty the sex differences get bigger. Performances of girls in several activities such as sprint and vertical jump do not improve after 14 to 15 years of age. The reason for this is not clear but both biological and cultural factors are discussed as possible explanations (Malina et al., 2004).

**The impact of height and weight for performance**

Individuals who are relatively older are generally taller and heavier than those born later in the year (Müller, Müller, Hildebrandt, Kornexl & Raschner, 2015). This statement was confirmed in studies by Torres-Unda et al. (2013), Carling, le Gall, Reilly and Williams (2009) and Gil et al. (2014), although a significant difference in body weight was not found in the two last mentioned studies. Correlations between body size and performance are generally low to moderate among adolescents up to 18 years of age, regardless sex, but there are some trends. For example, in sprints and jumps a negative correlation with body weight is often seen, whereas those who are tall and heavy tend to be strong (Malina et al., 2004). However, depending on the sport different factors are important and therefore influence RAE differently (Müller et al., 2015). A big body size is favourable in sports such as ice hockey (Sherar et al., 2007) and basketball (Torres-Unda et al., 2013), whereas successfully gymnastics are short and light (Bradshaw & Le Rossignol, 2004).
Relative age effect in sports

RAE has been investigated in many sports, especially football and ice hockey but also in individual sports such as tennis and swimming (Gutierrez Diaz Del Campo et al., 2010). Agricola, Zháněl and Hubáček (2013) investigated the distribution of birth date frequency among the 13 to 14 year old boys of the World Junior Tennis Finals from 2007 to 2011 and found that 38.9 % of the players were born in 1Q, while only 10.9 % were born in 4Q. The same trend was also found in a study by Gutierrez Diaz Del Campo et al. (2010). They examined RAE among Spanish football players in the age groups called Under 11, Under 13, Under 15, and Under 18. They found a biased distribution in the clubs where more players were born in 1Q than 4Q. Further, a stronger RAE was seen in elite clubs compared to amateur clubs. One possible explanation why RAE was stronger in the elite clubs was that boys born in the first months of the year tend to be selected for a team because of advanced maturity and thereby advantages in for example physique (Gutierrez Diaz Del Campo et al., 2010). This means that RAE has consequences not only in younger years, but also in the long term since the relatively older children tend to be selected to participate in higher teams where they might get better coaching and thereby an opportunity to further development and success (Wattie et al., 2008). But early maturation in adolescence is not a guarantee for good performance in adulthood (Philippaerts et al., 2006) since those who mature late usually catch up the early maturers during adolescence (National Strength & Conditioning Association, 2008). The development of technical qualities is also discussed as a reason for decreased influence of RAE in higher age (Delorme, Boiché & Raspau, 2010).

To avoid the fact that someone is selected for a higher team on the basis of early development (Jiménez et al., 2008) coaches are encouraged to focus more on technical and tactical skills when judging the performance (Helsen, van Winckel & Williams, 2005). Sufficient understanding about RAE is important, not only among coaches but also among children and their parents, to make all aware of that it is not possible to predict a child’s ability in a sport until full maturity is reached (Agricola et al., 2013). This is of certain importance for relatively younger individuals who tend to dropout from sports because of feelings of frustration and failure as they compare themselves to their older peers (Barnsley et al., 1985). Since RAE is assumed to be a possible reason for dropouts in sports (Delorme et al., 2010) RAE is thereby not only a problem in talent selection but also in the general health because of the long-term effects RAE might have.
**Relative age effect in physical performance**

Gil et al. (2014) examined if there was any relationship between RAE, anthropometry and performance in a group of 9 to 10 year old football players. Sprint, jump, and hand grip strength were some of the physical tests that were conducted. The study showed that players born in 1Q performed overall significantly better than players in 4Q. This indicated that there was a prevalence of RAE which was explained as an effect of differences in both body size and physical performance. The older individuals were taller and tended to be heavier, although the difference in weight was not significant (Gil et al., 2014).

Although much evidence suggests that relatively older adolescents are in advantage over younger peers regarding physical performance (Gil et al., 2014) there are studies which do not confirm the presence of RAE. A study of a group highly selected 14 to 16 year old football players showed no significant advantages in physical performance among the relatively older players (Carling et al., 2009). Neither a study by Malina, Ribeiro, Aroso and Cumming (2007) showed an evident relationship between relative age and physical performance in 14 year old football players.

Although the conclusions about RAE in the two previous mentioned studies and the one by Gil et al. (2014) were based on different physical tests such as sprint, agility, and vertical jump, few studies have investigated differences in physical performance regarding relative age in a sports context according to Sandercock, Taylor, Voss, Ogunleye, Cohen and Parry (2013). To the author’s knowledge RAE is often studied in terms of other aspects than physical performance, e.g. birth date distribution (Agricola et al., 2013), dropout (Delorme et al., 2010), prevalence in elite sport (Delorme, Boiché & Raspaud, 2009), and prevalence in different levels of competition (Gutierrez Diaz Del Campo et al., 2010). This was also claimed by Delorme et al. (2009) even though some research has been done since 2009.

Research of whether relatively older individuals have advantages in physical performance is still somewhat unclear (Sandercock et al., 2013). Additionally, the majority of the studies about RAE have investigated boys, which also was stated by Delorme et al. (2009). Since performance overall differs between sexes from about 14 years of age (Malina et al., 2004) it would be interesting to examine any differences in RAE between sexes.
Aim

The aim was to study relative age effects on anthropometric measures and physical performance in 13 year old adolescents who are active in sports.

Research questions:

- Are relatively older adolescents taller and heavier compared to relatively younger adolescents born in the same year?
- Do relatively older adolescents perform better in physical tests for grip strength, countermovement jump, and sprint compared to relatively younger adolescents born in the same year?
- Are there any differences in relative age effects between boys and girls?

Methods

This study was a cross-sectional study and part of the longitudinal “Malmö Youth Sport Study”.

Subjects

The subjects attended an upper secondary school with a sports profile in Malmö, Malmö idrottsakademi (MIA). To attend the school there are some admission criteria, amongst others technique, functional speed and coordination. Additionally, for some sports the students have to do test trainings to be admitted while other sports look at the students’ results in their sport. A range of different sports are represented at MIA, both individual and team sports. The sports that the subjects practiced are presented in Table 1. The cross-sectional part of Malmö Youth Sport Study included 136 subjects, however data concerning sex and month of birth were missing for some subjects (n=8), and therefore only 128 subjects were included in this study. All subjects turned 13 years of age during the year they were tested.
Table 1. Descriptives over the sports were available for 117 of the 128 included subjects.

<table>
<thead>
<tr>
<th>Sport</th>
<th>Number of practitioners (boys/girls)</th>
<th>Sport</th>
<th>Number of practitioners (boys/girls)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Football</td>
<td>45 (34/11)</td>
<td>Diving</td>
<td>6 (3/3)</td>
</tr>
<tr>
<td>Floorball</td>
<td>13 (7/6)</td>
<td>Ice hockey</td>
<td>5 (5/3)</td>
</tr>
<tr>
<td>Basketball</td>
<td>12 (7/5)</td>
<td>Badminton</td>
<td>3 (3/0)</td>
</tr>
<tr>
<td>Swimming</td>
<td>9 (3/6)</td>
<td>Figure skating</td>
<td>3 (3/0)</td>
</tr>
<tr>
<td>Track and field</td>
<td>9 (0/9)</td>
<td>Gymnastics</td>
<td>3 (3/0)</td>
</tr>
<tr>
<td>Tennis</td>
<td>8 (4/4)</td>
<td>Squash</td>
<td>1 (0/1)</td>
</tr>
</tbody>
</table>

Testing procedures

Two different seventh grade classes were tested in the autumn of 2014 and 2015, respectively, and the tests were conducted on either one day or on two days with one day in between. Before the physical tests the subjects performed an independent and non-standardised warm-up. The tests were not performed in any specific order. The subjects were divided into smaller groups, and when all in the group had performed one test they went to another one.

Relative age effect

To be able to investigate RAEs, the subjects’ date of birth was recorded and they were divided into groups based on the month of birth. Since there were too few subjects to divide them into four groups, like the majority of previous studies have done, the subjects were divided into three groups. Group 1 (Tertile 1 (T1)) included subjects born from 1 January to 30 April, group 2 (Tertile 2 (T2)) included subjects born from 1 May to 31 August, and group 3 (Tertile 3 (T3)) included subjects born from 1 September to 31 December.

Anthropometric measurements

Height was measured with a wall mounted stadiometer (4146, Hyssna Measuring Equipment AB, Hyssna, Sweden). The subject was told to stand erect with buttocks and shoulders against the stadiometer, let the hands hanging freely and to look straight ahead. The mean of two measurements was used for statistical analysis, but if there was a difference of more than 0.4 cm between the measurements a third was taken and the median of the three values was analysed. Every measurement was rounded to the nearest 0.1 cm (Canadian Sport for Life, 2011). Weight was measured with a digital personal weighting scale with column (SECA, Hamburg, Germany). Two measurements were recorded, but if there was a difference of more than 0.1 kg a third was taken and the median of the three values was analysed (Sherar et al.,
The anthropometric measurements were both conducted with the subject in bare feet and light clothing (Mikaelsson, Eliasson, Lysholm, Nyberg & Michaelson, 2011).

**Grip strength**

Grip strength was tested with a hand grip dynamometer (KERN MAP 80K1, KERN Sohn GmbH, Balingen, Germany) as a measure of strength. Grip strength shows large correlation to total muscle strength which indicate that it is a valid method to assess overall strength among children and adolescents (Wind, Takken, Helders & Engelbert, 2010). The test was performed in a seated position with the elbow in 90° angle. The forearm rested on a table with the wrist outside the edge of the table (Fess, 1992). The resistance of the hand grip dynamometer was 40 kg and the subject was told to press the shanks of the hand grip dynamometer together as hard as possible without any help. Three trials after each other were performed on the dominant hand. The results were rounded to the nearest 0.1 kg and the highest value was used for statistical analysis.

**Countermovement jump with arm swing**

Countermovement jump with arm swing (CMJ) was tested with an infrared mat (Muscle Lab, Ergotest Innovation, Porsgrunn, Norway) as a measure of explosive power of the lower limbs. CMJ is the most reliable and valid method for this purpose (Markovic, Dizdar, Jukic & Cardinale, 2004) although the arm swing influences the performance, which is further discussed in the methods discussion. The test was conducted with slight modifications to what Bellardini, Henriksson and Tonkonogi (2009) described. The test started from a standing position and the subject performed a rapid squat which was immediately followed by a maximal vertical jump. The squat and jump was assisted with an active arm swing. During the flight time hips and knees were extended. The subject landed with a double bounce with extended legs and with the toes touching the ground first (Bellardini et al., 2009). Three trials were performed after each other. Like in the study by Till and Jones (2015) the results were rounded to the nearest 0.1 cm and the best result was used for statistical analysis.

**20 m-sprint test**

A 20 m-sprint test was performed to measure acceleration and maximal speed. The time was measured with timing gates with photocells (Muscle Lab, Ergotest Innovation, Porsgrunn, Norway). A pair of timing gates was placed at start (0 m), 5 m, 10 m, and 20 m. The split time at 5 m was used to measure acceleration and the time between 10 m and 20 m was used to
measure maximal speed, since the time to cover the last 10 m is used to estimate maximal speed among children and adolescents in many sports (Bellardini et al., 2009). The subject was instructed to start in its own commando and to run as quickly as possible from a standing start 0.5 m behind the first timing gate. Three trials were performed and time was rounded to the nearest 0.01 s (Till et al., 2015). The best results at 5 m, 10 m, and 20 m, respectively, were used for statistical analysis (Bellardini et al., 2009). The subjects performed the sprint test in a specific order. After one trial the subjects rested until the rest of the group had run, and this was repeated twice.

**Ethical and social considerations**

Studies involving human subjects imply a number of ethical principles to relate to. The researcher is responsible for the health and integrity of the subjects and the subjects’ best is always in priority. Before the study began the subjects were informed of the study. The information included for instance the aim, methods, benefits and risks of the study. The subjects were also informed of their right to withdraw without explanation at any time during the study (World Medical Association, 2013). No irrelevant information was collected and the data was treated confidentially (Thomas, Nelson & Silverman, 2011).

For studies in which minors participate permission from parents or guardians of the children is required (Thomas et al., 2011). Therefore an informed consent (Appendix 1) was signed by the parents as well as the subjects themselves before the study began (World Medical Association, 2013). The study has been approved by the regional ethical review board in Lund, Dnr 2012/745, 2013/34 and 2014/270.

This study will contribute with information of whether relatively older adolescents perform better in physical qualities concerning strength, explosive power of the lower limbs, acceleration, and speed. This knowledge may be valuable in work with children and adolescence sports.

Although RAE in sports is not established, children and adolescents who are relatively older tend to perform better in physical tasks. Some studies have shown that RAEds have consequences in talent selection and also may be a reason for dropout from sport. Therefore it is a problem in the general health since those who take part in organised sports tend to be more physical active compared to individuals who do not participate (Crane & Temple, 2015). It is also found that physical activity and participation in sports in adolescence increase the probability to continue with a physical active lifestyle in adulthood (Tammelin, Näyhä,
Laitinen, Rintamäki & Järvelin, 2003). Because of the long-term effects RAE may have, further knowledge concerning the RAE on physical performance in adolescents is needed.

**Statistical analyses**

To analyse the RAE on anthropometric measures and physical performance, subjects born 1 January to 30 April (T1) were compared with subjects born 1 September to 31 December (T3). Only the extremes (T1 and T3) were compared since it was assumed that biggest differences would be found between these groups. To investigate if the data was normally distributed the Shapiro-Wilks test was used and all variables in T1 and T3 were normally distributed (p> 0.05) except weight in T1 (p=0.03). Independent-samples t-test was used to analyse differences in anthropometrics and physical performance between subjects born in T1 and T3. Further, the groups were divided by sex to be able to study boys and girls separately. Also a comparison between boys and girls in T1 and T3, respectively, was done to investigate sex differences. To account for body weight in the CMJ, a ratio was calculated by dividing jump height by body weight (CMJ weight ratio) according to Sandercock et al. (2013). The level of significance (α) was set at 0.05 in this study (Thomas et al., 2011). The results are presented as mean and standard deviation (±SD). SPSS Statistics 20.0 (IBM Corporation, Armonk, New York, USA) was used for the statistical analyses of the data.

**Results**

The study included 128 subjects, 78 boys (61%) and 50 girls (39%) who were 13 years old. When the subjects were divided into three groups based on month of birth, 70 (55%) were born January-April (T1), 31 (24%) were born May-August (T2), and 27 (21%) were born September-December (T3). A biased birth distribution was seen where more subjects were born early of the year compared to in the end of the year (Figure 1).
Figure 1. Number of subjects born in each of the three tertiles (Tertile 1=Jan-Apr, Tertile 2=May-Aug, Tertile 3=Sep-Dec).

Relative age effect
Subjects born in T1 were both taller (mean 163.5 ± 7.4 cm vs. 156.2 ± 7.5 cm, p=0.01) and heavier (52.3 ± 9.6 kg vs. 45.6 ± 6.9 kg, p=0.01) than subjects born in T3. Subjects born in T1 had greater grip strength than subjects born in T3 (27.9 ± 6.2 kg vs. 24.9 ± 5.8 kg, p=0.03). A statistically significant difference was also seen in CMJ weight ratio (0.7 ± 0.2 cm/kg vs. 0.8 ± 0.2 cm/kg, p=0.03) which indicated that subjects in T3 jumped higher per kilo body weight. Anthropometric measures and results of physical performance for all subjects are presented in Table 2, both for all subjects together and for each tertile separately.

Table 2. Anthropometrics and physical performance test results for all subjects, and comparison between T1 and T3, respectively.

<table>
<thead>
<tr>
<th>Measure</th>
<th>All Mean ± SD</th>
<th>T1 Mean ± SD</th>
<th>T2 Mean ± SD</th>
<th>T3 Mean ± SD</th>
<th>p (T1 vs T3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>161.3 ± 8.1</td>
<td>163.5 ± 7.4</td>
<td>160.6 ± 8.4</td>
<td>156.2 ± 7.5</td>
<td>0.01</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>49.6 ± 9.1</td>
<td>52.3 ± 9.6</td>
<td>47.0 ± 7.5</td>
<td>45.6 ± 6.9</td>
<td>0.01</td>
</tr>
<tr>
<td>Grip strength (kg)</td>
<td>26.8 ± 6.2</td>
<td>27.9 ± 6.2</td>
<td>26.0 ± 6.1</td>
<td>24.9 ± 5.8</td>
<td>0.03</td>
</tr>
<tr>
<td>Sprint 5m (s)</td>
<td>1.11 ± 0.06</td>
<td>1.10 ± 0.07</td>
<td>1.11 ± 0.05</td>
<td>1.11 ± 0.07</td>
<td>0.44</td>
</tr>
<tr>
<td>Sprint 10-20m (s)</td>
<td>1.48 ± 0.10</td>
<td>1.46 ± 0.09</td>
<td>1.50 ± 0.14</td>
<td>1.49 ± 0.09</td>
<td>0.26</td>
</tr>
<tr>
<td>CMJ (cm)</td>
<td>33.8 ± 5.4</td>
<td>33.9 ± 5.8</td>
<td>33.2 ± 3.8</td>
<td>34.0 ± 6.0</td>
<td>0.98</td>
</tr>
<tr>
<td>CMJ weight ratio (cm/kg)</td>
<td>0.7 ± 0.2</td>
<td>0.7 ± 0.2</td>
<td>0.7 ± 0.1</td>
<td>0.8 ± 0.2</td>
<td>0.03</td>
</tr>
</tbody>
</table>

All=January-December, Tertile 1=January-April (T1), Tertile 2=May-August (T2), Tertile 3=September-December (T3), Countermovement jump (CMJ)

*Measurements for weight and CMJ were missing for different subjects.
Differences in relative age effects within the sexes

Boys in T1 were statistically significant taller (164.1 ± 8.7 cm vs. 154.7 ± 6.6 cm, p=0.01) and heavier than boys in T3 (51.0 ± 10.7 kg vs. 44.2 ± 6.4 kg, p=0.02). Further, the boys in T1 performed better in grip strength (28.3 ± 6.8 kg vs. 24.3 ± 6.4 kg, p=0.05) which was the only physical test where a statistically significant difference was found (Table 3).

Table 3. Anthropometrics and physical performance test results for boys and comparison between T1 and T3, respectively.

<table>
<thead>
<tr>
<th></th>
<th>T1 (Jan-Apr)</th>
<th>T1</th>
<th>T3 (Sep-Dec)</th>
<th>T3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean ± SD</strong></td>
<td></td>
<td></td>
<td><strong>Mean ± SD</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td>164.1 ± 8.7</td>
<td>42</td>
<td>154.7 ± 6.6</td>
<td>15</td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td>51.0 ± 10.7</td>
<td>41</td>
<td>44.2 ± 6.4</td>
<td>15</td>
</tr>
<tr>
<td><strong>Grip strength (kg)</strong></td>
<td>28.3 ± 6.8</td>
<td>42</td>
<td>24.3 ± 6.4</td>
<td>15</td>
</tr>
<tr>
<td><strong>Sprint 5m (s)</strong></td>
<td>1.09 ± 0.07</td>
<td>37</td>
<td>1.12 ± 0.07</td>
<td>15</td>
</tr>
<tr>
<td><strong>Sprint 10-20m (s)</strong></td>
<td>1.45 ± 0.09</td>
<td>37</td>
<td>1.49 ± 0.11</td>
<td>15</td>
</tr>
<tr>
<td><strong>CMJ (cm)</strong></td>
<td>35.4 ± 5.5</td>
<td>37</td>
<td>35.2 ± 5.5</td>
<td>15</td>
</tr>
<tr>
<td><strong>CMJ weight ratio (cm/kg)</strong></td>
<td>0.7 ± 0.2</td>
<td>36*</td>
<td>0.8 ± 0.2</td>
<td>15</td>
</tr>
</tbody>
</table>

Countermovement jump (CMJ)

*Measurements for weight and CMJ were missing for different subjects.
Among the girls statistically significant differences were found in weight where girls in T1 were heavier than girls in T3 (54.3 ± 7.5 kg vs. 47.4 ± 7.3 kg, p=0.01) and in CMJ weight ratio where girls in T3 had a higher ratio (0.6 ± 0.1 cm/kg vs. 0.7 ± 0.2 cm/kg, p=0.05) compared to girls in T1 (Table 4).

Table 4. Anthropometrics and physical performance test results for girls and comparison between T1 and T3, respectively.

<table>
<thead>
<tr>
<th></th>
<th>T1 (Jan-Apr)</th>
<th>T1 n</th>
<th>T3 (Sep-Dec)</th>
<th>T3 n</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td></td>
<td>Mean ± SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>162.6 ± 4.6</td>
<td>28</td>
<td>157.9 ± 8.4</td>
<td>12</td>
<td>0.09</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>54.3 ± 7.5</td>
<td>27</td>
<td>47.4 ± 7.3</td>
<td>12</td>
<td>0.01</td>
</tr>
<tr>
<td>Grip strength (kg)</td>
<td>27.4 ± 5.2</td>
<td>28</td>
<td>25.6 ± 5.1</td>
<td>12</td>
<td>0.31</td>
</tr>
<tr>
<td>Sprint 5m (s)</td>
<td>1.11 ± 0.06</td>
<td>27</td>
<td>1.11 ± 0.06</td>
<td>12</td>
<td>0.94</td>
</tr>
<tr>
<td>Sprint 10-20m (s)</td>
<td>1.48 ± 0.08</td>
<td>27</td>
<td>1.48 ± 0.08</td>
<td>12</td>
<td>0.84</td>
</tr>
<tr>
<td>CMJ (cm)</td>
<td>32.0 ± 5.6</td>
<td>27</td>
<td>32.5 ± 6.6</td>
<td>12</td>
<td>0.78</td>
</tr>
<tr>
<td>CMJ weight ratio (cm/kg)</td>
<td>0.6 ± 0.1</td>
<td>26*</td>
<td>0.7 ± 0.2</td>
<td>12</td>
<td>0.05</td>
</tr>
</tbody>
</table>

*Measurements for weight and CMJ were missing for different subjects.

Differences between the sexes

When boys and girls in T1 were compared, the only statistically significant differences found were in CMJ (35.4 ± 5.5 cm vs. 31.9 ± 5.6 cm, p=0.02) and in CMJ weight ratio (0.7 ± 0.2 cm/kg vs. 0.6. ± 0.1 cm/kg, p=0.01) where the boys jumped higher and got a higher ratio than the girls (Table 5). A comparison was also made between sexes in T3 but no statistically significant differences were found (Table 6).
Table 5. Anthropometrics and physical test results for T1 and comparison between boys and girls, respectively.

<table>
<thead>
<tr>
<th></th>
<th>T1 Boys Mean ± SD</th>
<th>T1 Boys n</th>
<th>T1 Girls Mean ± SD</th>
<th>T1 Girls n</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>164.1 ± 8.7</td>
<td>42</td>
<td>162.6 ± 4.6</td>
<td>28</td>
<td>0.35</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>51.0 ± 10.7</td>
<td>41</td>
<td>54.3 ± 7.5</td>
<td>27</td>
<td>0.17</td>
</tr>
<tr>
<td>Grip strength (kg)</td>
<td>28.3 ± 6.8</td>
<td>42</td>
<td>27.4 ± 5.2</td>
<td>28</td>
<td>0.57</td>
</tr>
<tr>
<td>Sprint 5m (s)</td>
<td>1.09 ± 0.07</td>
<td>37</td>
<td>1.11 ± 0.06</td>
<td>27</td>
<td>0.25</td>
</tr>
<tr>
<td>Sprint 10-20m (s)</td>
<td>1.45 ± 0.09</td>
<td>37</td>
<td>1.48 ± 0.08</td>
<td>27</td>
<td>0.10</td>
</tr>
<tr>
<td>CMJ (cm)</td>
<td>35.4 ± 5.5</td>
<td>37</td>
<td>31.9 ± 5.6</td>
<td>27</td>
<td>0.02</td>
</tr>
<tr>
<td>CMJ weight ratio</td>
<td>0.7 ± 0.2</td>
<td>36*</td>
<td>0.6 ± 0.1</td>
<td>26*</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Tertile 1=January-April (T1), Countermovement jump (CMJ)

*Measurements for weight and CMJ were missing for different subjects.

Table 6. Anthropometrics and physical test results for T3 and comparison between boys and girls, respectively.

<table>
<thead>
<tr>
<th></th>
<th>T3 Boys Mean ± SD</th>
<th>T3 Boys n</th>
<th>T3 Girls Mean ± SD</th>
<th>T3 Girls n</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>154.7 ± 6.6</td>
<td>15</td>
<td>157.9 ± 8.4</td>
<td>12</td>
<td>0.28</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>44.2 ± 6.4</td>
<td>15</td>
<td>47.4 ± 7.3</td>
<td>12</td>
<td>0.24</td>
</tr>
<tr>
<td>Grip strength (kg)</td>
<td>24.3 ± 6.4</td>
<td>15</td>
<td>25.6 ± 5.1</td>
<td>12</td>
<td>0.57</td>
</tr>
<tr>
<td>Sprint 5m (s)</td>
<td>1.12 ± 0.07</td>
<td>15</td>
<td>1.11 ± 0.06</td>
<td>12</td>
<td>0.87</td>
</tr>
<tr>
<td>Sprint 10-20m (s)</td>
<td>1.49 ± 0.11</td>
<td>15</td>
<td>1.48 ± 0.08</td>
<td>12</td>
<td>0.70</td>
</tr>
<tr>
<td>CMJ (cm)</td>
<td>35.2 ± 5.5</td>
<td>15</td>
<td>32.5 ± 6.6</td>
<td>12</td>
<td>0.26</td>
</tr>
<tr>
<td>CMJ weight ratio</td>
<td>0.8 ± 0.2</td>
<td>15</td>
<td>0.7 ± 0.2</td>
<td>12</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Tertile 3=September-December (T3), Countermovement jump (CMJ)
**Discussion**

The aim of this study was to investigate if any RAEs were found in a group of 13 years old adolescents who are active in sports and attending a school with a sports profile. A biased birth distribution was seen where subjects born early in the year were over represented, and findings differed depending on sex. Older boys born January to April were taller, heavier, and stronger than the younger ones born September to December, while older girls were heavier and jumped lower per kilo in CMJ than the younger girls did.

**Results discussion**

**Relative age effect**

When all subjects were analysed together RAEs were found in height, weight, and grip strength, but the results in sprint and CMJ did not differ between those born early in the year and those born late in the year. According to Malina et al. (2004) it tends to be a positive correlation between height and weight and strength. This means that subjects who are taller and heavier are stronger which was found in this study. Further, Malina et al. (2004) meant that low body weight tends to correlate with good performance in sprints and jumps which partly supports the findings in the present study. Subjects who were lighter performed better in CMJ, but only when the result of the jump test was displayed as relative jump height, i.e. the CMJ weight ratio. Therefore this result indicated that there was a weight effect rather than an age effect, which means that heavier subjects had an advantage in grip strength whereas lighter subjects had an advantage in CMJ. On the other hand, subjects who are born early in the year tend to be heavier (Malina et al., 2004), thus the results could still be called RAEs. However, the mean difference of 0.1 cm/kg in the CMJ weight ratio does probably not have any importance in practice.

Helsen et al. (2005) meant that selection within sports is often based on body size, thereby relatively older subjects tend to be in advantage. This is of course unfortunate as many talented athletes might be deselected in a selection process just because they are small (Helsen et al., 2005), especially as the task determines whether a big body size is an advantage or disadvantage, which the results from this study showed. For example, in ice hockey and rugby both strength and speed are some of several physical qualities needed (Sherar et al., 2007; Till et al., 2015) and both are contact sports where a big body size is an advantage. Because of the wide range of demands in many sports and the fact that RAE was only found in one
performance (grip strength) in this study, indicates that physical performance alone should not be used in selection processes.

**Differences in relative age effects within the sexes**

To see if there were any differences in RAEs within the sexes, analyses were done on boys and girls separately. This is of interest since PHV, which is an indicator of maturity and a factor related to physical performance, occurs earlier in girls than in boys (Malina et al., 2004). According to this it is assumed to be less pronounced RAEs among the girls.

The older boys performed better in grip strength, and in line with the study by Torres-Unda et al. (2013) in which 13 to 14 year old male basketball players were studied, the older boys were taller and heavier than their younger peers. However no RAE was found in CMJ, in contrast to the result from Torres-Unda et al. (2013) where the older subjects performed better. Although relatively older subjects are assumed to perform better in physical tasks because they are more mature (Gil et al., 2014), other factors such as weight might be a stronger determining factor which was previously discussed.

In the study by Gil et al. (2014), who investigated RAE among 10 year old male football players, it was found that the relatively older players performed better in speed and agility tests and got better results in a calculated overall performance score than the younger players. But no differences were found in CMJ or grip strength. A stronger evidence of RAE in physical performance in their study compared to this might be because the subjects were pre-pubertal, thus the relative age might have more influence on performance whereas its influence decreases during puberty.

In the analysis of the girls, there were only differences in weight and CMJ weight ratio which indicated that the younger girls were lighter and jumped higher per kilo body weight. A similar result was found by Sandercock et al. (2013) who also analysed boys and girls separately and found stronger RAEs in boys too. The fact that Sandercock et al. (2013) studied schoolchildren aged 10 to 16 years made it difficult to compare their findings with this study. However, the mean as well as median age of their subjects were 13 years, and the authors referred the difference in RAE between the sexes to differences in level of maturity and that most of the girls were pubertal at this age, whereas the level of maturity probably varied more among the boys. The same reasoning could be used to explain the results in this study. Since the subjects were 13 years old the majority of the girls are supposed to have
passed PHV and therefore be more equally mature. According to Sherar et al. (2007) it is important to assess maturity in studies of adolescents because of the large variability in maturity in this age. Unfortunately this kind of information was not available in this study.

**Differences between the sexes**

In the analysis where boys in T1 were compared with girls in T1, RAEs were only found in CMJ and CMJ weight ratio where the boys performed better, while no differences in either anthropometric measures or physical performances were found between the sexes born late in the year. According to Malina et al. (2004) differences in performance between boys and girls in early adolescence are not very big in general. Since Malina et al. (2004) meant that sex differences appear during puberty, it might partly explain the results from the analysis between sexes. Maybe it would have been possible to find bigger differences if subjects of a higher age were studied. Further, the absence of differences between boys and girls born late in the year might be explained by a type II error due to the low number of subjects.

An overall discussion why few RAEs in physical performance were found could be explained in line with the discussion by Torres-Unda et al. (2013), Carling et al. (2009) and Sandercock et al. (2013) who meant that the existing admission criteria to enter the school might already have deselected the “less talented” subjects. Thereby the level of physical performance is relatively equal regardless relative age or anthropometric measurements. Further it could be assumed that the admission criteria have influenced the birth distribution, and thereby indicate a presence of RAE where relatively older subjects indeed had an advantage in the selection process. A second reason given by Sandercock et al. (2013) why few differences were found could be that the relatively younger subjects are more mature and do better in physical performance than other in their age, hence they are not representative of their age.

The fact that the subjects practiced different sports could be one factor which made it difficult to find RAEs in physical performances since the demands of a sport can differ considerable from another one. If subjects from the same sport was analysed separately, perhaps the relatively older subjects would have been better than the younger ones. But in this study there can be many of the subjects born late in the year who participate in sports where sprints, jumps, or other powerful movements are common. By this any RAEs could be compensated because they are more experienced of sprints and jumps. For this reason it would have been interesting to analyse subjects in each sport separately if the sample size was larger and if complete data over the number of practitioners in each sport would have been available.
However both Malina et al. (2007) and Carling et al. (2009) studied football players but they still did not find any RAE despite all subjects practised the same sport.

**Methods discussion**

Some general standardisations for the testing procedure could have been to tell the subjects to avoid strenuous training before the tests since this can affect the performance negatively. However this was not possible since the subjects train every day. Further, if all or the majority of the subjects were assumed to train the day before the tests, the results are less influenced. In addition, it would have been preferable if the tests were performed in a specific order so that all subjects would have had the same level of fatigue before the tests.

**Subjects**

Since too few subjects were born in the end of the year it was not possible to divide the group into quartiles which would have facilitated comparisons with other studies. Instead tertiles were used, but the low number of subjects in T3 could have affected the results since it is easier to detect differences in larger samples. The low number of subject increased the risk of a type II error were the null hypothesis is incorrectly accepted, thus no differences were found even though there might be differences (Thomas et al., 2011).

**Anthropometric measurements**

The time of the day when the measurements were taken was not known to the author but is some factor to consider as this influence the results. Weight increases during the day whereas height decreases by as much as a centimeter or more (Malina et al., 2004).

**Grip strength**

As mentioned in the methods grip strength is a valid method to assess overall strength among children and adolescents (Wind et al., 2010). In addition, the test is fast and easy to perform (Innes, 1999) which makes it suitable to use when large groups are tested. When maximum grip is measured the mean of three trials are often used. However, variations to this method, such as using the highest value of three trials which was the case in this study, have not showed significantly different reliability (Innes, 1999). According to Innes (1999) it is not necessary to rest between trials since periods of rest only have minor influences on the results. On this basis the subjects performed three consecutive trials which also made the test procedure less time consuming.
Countermovement jump with arm swing

CMJ is the most reliable and valid test to estimate explosive power in the lower limbs if it is measured with a contact mat that is connected to a digital timer (Markovic et al., 2004). When CMJ is performed with arm swing the jump is affected and expected to be higher compared to a CMJ without arm swing. But the use of the arms is in favour only if the subject is able to coordinate their movement during the jump (Bellardini et al., 2009) which makes this test not only a measurement of explosive power but also a test of coordination as the arm swing becomes a confounding variable (Alemdaroğlu, 2012) thus the validity of the test is decreased. On the other hand, jumps without arm action are unusual in sports (Vescovi, Rupf, Brown & Marques, 2011) hence why CMJ with arm swing could be considered suitable. During the rapid squat the subjects did not have to reach 90° knee flexion unlike what Bellardini et al. (2009) said since it would have been difficult to ensure the correct angle. Instead the subjects were told to decline to a knee angle were they got maximal power. A standardised knee angle would have been preferable to make the test more reliable, but the choice to not reach 90° made the test easier and more effective to conduct. Regarding rest between the trials Markovic et al. (2004) suggested a 1-minute rest, but since the subjects only performed three jumps fatigue was not assumed to affect the performance negatively.

The reason why a CMJ weight ratio was calculated was to see how weight influenced jump and thereby see how high the subjects jumped per kilo body weight. Since RAE was found when CMJ was presented as a CMJ weight ratio but not as an absolute jump height, it would have been interesting to present the other variables relative to weight as well to see if additional differences could be found. All results from the physical tests in the study by Sandercock et al. (2013) were presented relative to weight since they meant that comparisons among adolescents might be fairer if strength and power are expressed relative to body weight.

20 m-sprint test

20 metre is assumed to be an appropriate distance to measure maximal speed since players in most team sports do not run longer than 20 metre. According to this, the subjects would not be able to keep a maximal speed for a longer distance (Bellardini et al., 2009) and thereby the result would not be valid. However, subjects who have a high maximal speed are able to accelerate a longer distance before the maximal speed is reached. Therefore Bellardini et al.
(2009) suggest a flying-sprint test as a complement to the used 20-m sprint test. To increase the reliability of the test a standardised time of rest would have been preferable.

**Conclusions**

The results showed RAEs on some anthropometric measures, but less clear RAEs were found in physical performances in the 13 year old subjects. This indicates that although relatively older adolescents are taller and heavier, the bigger body size is not necessarily in their advantage. To investigate if the results from this study are reliable, future studies in this area should investigate larger sample sizes. Additionally, it is not sure that the same results would have been found in adolescents at another age or in subjects who do not attend to a school with a sports profile. Therefore studies that include adolescents at another age and attending ordinary schools would be interesting.
References


Appendix 1

Malmö Youth Sport Study

Förfrågan om deltagande
Vi frågar dig om du vill delta i en studie av hur vilken betydelse idrottsskolor har för kontinuerligt och framgångsrikt idrottande. Vi frågar även dina föräldrar om deras tillåtelse och om att svara på en enkät.

Bakgrund och syfte

Hur går studien till?
Studien består av två delar:

- Undersökning av en rad fysiologiska faktorer, inställning till idrott och fysisk aktivitet, sociala faktorer och inställning till könsskillnader vid upprepade tillfällen hos ungdomar vid Malmö idrottsgrundskola.
- En jämförelse av inställning till idrott och fysisk aktivitet, sociala faktorer och inställning till könsskillnader vid upprepade tillfällen mellan ungdomar vid Malmö idrottsgrundskola och ungdomar vid andra grundskolor i Malmö.

Fysiologiska faktorer: Dessa undersöks vid ett besök vid Klinisk fysiologi, Diagnostiskt centrum, SUS i Malmö. Följande undersökningar görs: Mätning av kroppssammansättning (muskel massa, fett massa), fysisk arbetsförmåga på testcykel, muskelstyrka, lungfunktion, hjärtfunktion med ultraljudsundersökning och EKG och blodtryck. Arbetsprovet på testcykel och styrketesterna innebär ansträngning liknande den vid träning av idrott.

Lungfunktionsundersökningen innebär att man andas på olika sätt genom ett munstycke. Övriga undersökningar kräver ingen medverkan. Dessutom mäts fysisk aktivitet under en vecka med en mätare som bärs i ett bälte runt midjan.

Inställning till idrott: Denna undersöks med frågeformulär som ungdomar och föräldrar får besvara.
Sociala faktorer: Dessa undersöks med frågeformulär som ungdomar och föräldrar får besvara.

Könsskillnader belyses genom att en forskare följer några ungdomar under skoltid och träning och passivt observerar deras aktiviteter. Dessutom kommer några ungdomar att ingå i så kallade fokusgrupper där man vid några tillfällen träffas för att diskutera om pojkar och flickor har olika inställning till idrotten och skolan. Alla individer kommer alltså inte att bli engagerade i denna del av studien.

Vi kommer att be dig att genomföra tester och enkäter vid tre tillfällen med ett par års mellanrum.

Vilka är riskerna?

Alla undersökningarna används rutinmässigt i sjukvården och ingen är förenad med några risker. Ingen undersökning innebär blodprovstagnings eller andra smärtsamma moment.

Finns det några fördelar?

Utöver information om arbetsförmåga och muskelstyrka innebär undersökningen inga fördelar för forskningspersonerna.

Hantering av data och sekretess


Hur får jag information om studiens resultat?

Du kommer att få besked om resultatet av din arbetsförmåga och din muskelstyrka.

Försäkring

Du är skyddad av Patientförsäkringen under studien liksom i samband med vanlig sjukvård.
Frivillighet

Deltagande i studien är helt frivilligt. Deltagande i delstudien om könsrelaterade faktorer kommer att baseras på intresse. Du kan när som helst och utan att ange särskild anledning avbryta ditt deltagande. All insamlad information kommer då att förstöras.

Ansvariga

Forskningshuvudman och personuppgiftsansvarig är Region Skåne. Personuppgiftsombud i Region Skåne är Eva Plym Forshell (Enhet för informationssäkerhet, Region Skåne, Dockplatsen 26, Malmö, tel. 040-675 32 24).

Ansvariga forskare är

Magnus Dencker
Docent, överläkare
Klinisk fysiologi, Diagnostiskt centrum
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Tel. 040-338731

Per Wollmer
Professor, överläkare
Klinisk fysiologi, Diagnostiskt centrum
Ingång 44, SUS Malmö
Tel. 040-331441
Jag har informerats om studien av ……………………………………. och accepterar att delta. Jag accepterar att mina personuppgifter hanteras på det sätt som beskrivits.

Malmö den

______________________________
Namnteckning

______________________________
Namnförtydligande

Jag har tagit del av informationen ovan och accepterar att min dotter/son deltar i studien. Jag accepterar också att besvara föräldraenkäten.

Malmö den

______________________________
Namnteckning

______________________________
Namnförtydligande

Jag har lämnat information om studien.

Malmö den

______________________________
Namnteckning

______________________________
Namnförtydligande
Martina Eriksson