"Hand reach star excursion balance test"
Assessment of dynamic functional mobility in female elite team gymnasts in relation to overuse injuries

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"Hand reach star excursion balance test”
- Undersökning av dynamisk funktionell rörlighet
hos kvinnliga elittruppgymnaster i relation till överbelastningsskador

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- Assessment of dynamic functional mobility in female
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Författare: Åsa Bocké
Abstract

Background
Clinical usable assessment methods to quantify mobility, balance, stability and postural control functions together in a full kinetic chain movement are sparse. Normative data of such dynamic functions in different group of athletes are still lacking and therefore the relationship between dynamic functional mobility and overuse injuries are also unknown. The prevalence of overuse injuries among adolescent athletes are continuously high and team gymnastic is one example of a sport with multiple and underestimated overuse injuries.

Aim
The first aim of study was to establish normative data of dynamic functional mobility in a group of elite team gymnasts. The second aim was to investigate ongoing overuse injuries and evaluate associations between ongoing overuse injuries and dynamic functional mobility in the group.

Method
A descriptive cross sectional study including 31 female elite team gymnasts 16-19 years old were conducted. “The hand reach star excursion balance test” (HSEBT) was used to measure dynamic functional mobility in 20 different movement patterns. The "Oslo Sports Trauma Research Center Overuse Injury Questionnaire"(OSTRC) was used to record and analyse severity of ongoing overuse injuries in the group. Pearson correlation analysis was used to determine the relationship between the scoring in the HSEBT- tests and scoring on the OSTRC.

Results
A majority of the participants presented with scores near the maximum values on the HSEBT. Further, 97% of the subjects had an ongoing overuse injury. Severe injuries, affecting participation in sport were present in 67%. Correlations was found between prevalence of severe injury in the lower back and lower scoring on the right leg in a rotational movement pattern ($r= -0.42$) whereas prevalence of severe injury in the hip was associated with extreme high mobility in a sidebending pattern in both legs ($r= 0.50, 0.49$). There was also a relationship between individuals with multiple severe overuse injuries and dynamic functional mobility in an extended movement pattern of the left leg ($r= -0.36, -0.38$).

Conclusion
Normative data of dynamic functional mobility according to the HSEBT can provide clinicians with reference points to compare elite female team gymnasts. There was an indication of association between limited mobility in some of the included tests and prevalence of overuse injuries in the lower back and hip. This study included a small sample and therefore conclusions have to be interpreted carefully.

Keywords: adolescents, functional tests, injury prevalence, movement screening
**Background**

As a physiotherapist involved in the assessment and treatment of youth athletes it is challenging to choose the most appropriate and clinical usable assessment tool that targets dynamic movement functions as well as sports performance. In Orthopedic manual therapy (OMT), which is a specialized area of physiotherapy, the assessment methods serve to define the presenting dysfunction(s) in the articular, muscular, nervous and other relevant systems and how these relate to any disability or functional limitation (1). Currently many of the assessment tools in the OMT field of physiotherapy are measures of single components of movement, for example measurements of uniplanar passive joint mobility with a goniometer. These tests lack the ability to determine how an individual is able to use the body in a full kinetic chain movement and therefore perform or function with efficiency (1-3).

**Screening tools and test batteries for dynamic functions**

In sports medicine different screening tools for assessment of so called "functional movements” and screening of "global movement patterns" have been popular and are still common. These screening tools are used to analyse and optimize athletic performance and often contain a "mixture" of mobility, strength, balance and multi joint tasks (4, 5). The motivation for using these screening tools has been that they represent fundamental movements that are characteristic of many sports and can therefore be used as measurements of these capacities. In advanced sports medicine tests of dynamic components such as change of direction (COD), different agility- or jump tests have also been used with the aim to detect abnormal kinematic motion across multiple planes (5, 6). This requires both expensive and complicated equipment and is not common in the youth athletic population nor in the normal physiotherapy setting.

Other aims with these tests have been to detect weak links in the kinetic chain, asymmetrical movement patterns as well as it’s correlation to injury or overuse (7, 8). Some of the most common functional tests for athletes described in the literature is the Functional movement screen (FMS), the Movement competency screen (MCS) and in Sweden the "Nine screening battery" (9+) (8-12). Even though some of these instruments demonstrates significant association with higher injury risk they have been questioned about their relevance for sport specific movements as well as for its validity and sensitivity (4, 8). When it comes to its ability to predict injury among athletes there is argumented that no such instrument has
enough accuracy (7, 8). Association with a specific result on a functional test and sports performance is also not yet known (4, 7). Another problem with the interpretation and evaluation of screening test or assessment batteries is the lack of reference values and normative values for dynamic functions. Heterogeneity in studies as well as individual movement strategies are commonly described as confounders in this research field (4, 5, 13).

The hand reach star excursion balance test (HSEBT)

One test battery that has been developed to evaluate dynamic functional mobility and postural control during movement is “The hand reach star excursion balance test “(HSEBT). It contains similarities to the well-established and reliable instrument of dynamic postural control "Star excursion balance test" (SEBT) but adds both trunk and upper extremity movements since it is based upon hand reaches (3, 14). The aim of this instrument is to capture neuromuscular control involved in synergistic movements in the kinetic chain such as mobility, balance, proprioception, posture, and placement of center of mass. The test elicits movements in all three movement planes in so called movement synergies or coupled motions while the subject is reaching in eight different directions (measures in centimeters) and rotates (measures in degrees) in 2 directions standing on left and right leg respectively (figure 1). Every reach- and rotational test can then be analysed. Joint mobility as well as balance and postural control will affect the result of the tests and a longer reach-or rotation distance gives higher scores. The reach and rotational tests are named after the vectors. There are three tests in a flexion pattern (R45, LAO, L45), three reach tests in an extension pattern (L135, P180, R135) and two reach tests in a lateral flexion pattern (L90, R90) and two rotational tests (Rrot, Lrot) on each leg (15). The obtained measurements can be analyzed in a spider diagram as shown in figure 2. The HSEBT has shown to be both valid and reliable but to this date there is only one article that describes reference values for healthy male subjects at the age of 23-28 year on all included tests (3).
Figure 1 Maximum reach position of HSEBT reaches and rotations standing on the right foot. (The picture is showing the original mat 2 x 2 metres. (reprinted from Eriksrud et al. 2019. Functional Mobility and Dynamic Postural Control Predict Overhead Handball Throwing Performance in Elite Female Team Handball Players. Journal of Sports Science & Medicine, 18(1), 91–100. Copyright 2019 with permission from the JOURNAL OF SPORTS SCIENCE AND MEDICINE.)

Figure 2. HSEBT profile of test values from the article by Eriksrud et al 2017 where 29 recreationally active, healthy male subjects participated (age 25.4 ± 6.4 years; height 180.0 cm). Inner circles in the diagram represents all reach tests and the outer circle represents two rotational tests on each leg.
Overuse injury registration

Overuse injury registration has traditionally been "time loss from sport" which underestimates the effect of an injury with a gradual onset. Many athletes, not only gymnasts, continue to train and compete despite symptoms of overuse and it can be a challenge to identify the onset of an overuse injury. Therefore methods have been developed to judge both the severity of symptoms as well as the effect of symptoms on participating in sport (16). Reporting of prevalence (the proportion of athletes affected by problems at any given time) and not incidence (the number of new cases during a specific period of exposure) might also describe the overuse situation in a more appropriate way (17). The self-reporting questionnaire “Oslo Sports Trauma Research Center Overuse Injury Questionnaire” (OSTRC) has been developed by Clarsen et al. (2013) with the goal to collect data about consequences of health problems on sports participation, training volume and degree of symptoms. The questionnaire contains four questions, for each chosen body region, about effects on sports participation, training volume, performance and pain experience and takes about ten minutes to complete (figure 4). The answers of the questions have different values with the aim to sort out more substantial problems from just a recording of a “symptom”. It is also possible to calculate a severity score and to rank an injury as severe or not severe. OSTRC has proven to be both valid and sensitive and it has been translated into Swedish (16, 18). It is described as useful in clinical practice as well as in research (18).

Team gymnasts and overuse injuries

Team gymnastics are a very popular sport in Sweden, engaging many athletes at a very young age with demands on extremely high training volumes and early specialization. Overuse injuries of the spine and lower extremities are described as frequent in this population and it is common that athletes train and compete with ongoing injuries (19). This might contribute to different compensatory movement patterns affecting both mobility, strength and balance and therefore performance and highlights the need to assess these components in a relevant way (20). There is not much literature concerning injury mechanisms and contributing factors of overuse in the adolescent team gymnast (19). Most studies concern artistic gymnastics or acute injuries (19, 21-23). Several studies in the gymnastic field as well as the youth athlete research area describes the need to identify risk factors for injury, perform data on injury trends and to develop better injury preventive measures (19, 21).
Knowledge gap

All individuals have different ways to use the kinetic chain and combine joint angles to accomplish a movement. This can be due both to intrinsic differences in muscle length, muscle stiffness, core stability, balance etc. as well as differences in movement strategies. Since decreased range of movement of specific joints have been found to impact joint movements in other parts of the kinetic chain it can be motivated to assess dynamic functional mobility (15, 24, 25). To our knowledge there is still lack of instruments to quantify mobility, balance, stability and postural control functions together in a full kinetic chain movement (26). The association between a result of a screening instrument and an ongoing overuse injury is still not fully known, both due to methodological issues as well as the recording of injuries (17, 22, 27). Physiotherapists involved in screening, testing and evaluation of different athletes needs to be part of the development of relevant clinical useful screening instruments and injury registration methods to continue the work towards evidence-based methods. This might start with clinical trials and establishing normative data for different athletic populations (5). Therefore the first aim of the present study was to establish normative data of dynamic functional mobility in a group of elite team gymnasts. The second aim was to investigate ongoing overuse injuries and evaluate associations between ongoing overuse injuries and dynamic functional mobility in the group.

Methods

Study design

This study had a descriptive cross-sectional design. To assess dynamic functional mobility the Hand reach star excursion balance test (HSEBT) was used. To record overuse injuries the "Oslo Sports Trauma Research Center Overuse Injury Questionnaire"(OSTRC) was used. The study was approved by the local ethical group at Luleå University of Technology, Division of Health Sciences, in January 2018 (dnr: LTU-325-2018). The approval refers to a simplified ethical application, reviewed by a local ethical group assessing student essays at advanced level. The recruitment process, assessment and all handling of the data were carried out in compliance of the Helsinki declaration of human research (28).

Study Sample
Female elite team gymnasts between 16-20 years of age were included in the study. Gymnasts with serious physical dysfunctions, such as fractures, nerve damages, total muscle- or ligamentous injuries during the last three months, were excluded. The number of participants were chosen according to at least have a middle size group of participants of 20-50 persons (29).

**Procedure**

Recruitment and testing of participants started in March 2018. All the clinical tests were finished by November 2018. The head coach of totally ten team gymnast clubs in Stockholm were contacted and invited to participate in the study and six clubs agreed. The head coach of every club received and distributed the information about the study to the participants (Appendix 1) including handling of a written consent as well as the OSTRC (Appendix 2,3). The participants gave their written consent by responding by email directly to the author (Appendix 2). They also filled out the OSTRC questionnaire at the same time. 35 persons agreed to participate by responding by email. During the clinical test period totally four gymnasts from two different clubs choose to cancel their participation due to lack of time. A total of 31 female elite team gymnasts were therefor includes in the study.

The clinical tests was performed by a physiotherapist with good experience in the methodology of the HSEBT as well as 20 years clinical experience of movement analysis. The clinical tests were conducted just before their normal training session started. All measurements were recorded into a computer program developed by Athletic Knowledge Nordic AB, Stockholm https://1080map.com.

**Outcome measurements**

**Hand reach star excursion balance test (HSEBT)**

During testing the participants were standing on the mat barefoot wearing shorts and t-shirt. Information of the standard procedure of measuring as well as hand- and foot placement during testing were given to all participants before testing (3, 15). The subjects were instructed to place the foot in the center of the mat and the other foot as balance support. The instructions for the tests were to reach or rotate as far as possible and then returning to the starting position while maintaining balance. Each test were performed three times and the maximum reach were recorded. The test took around 30 minutes. The test mat used in this
study measured 140 x 60 centimeters and is a portable version to be used in clinical situations (figure 3). The mat has 10 imprinted circles at 10 centimeters interval, the outer circle is 90 cm radius with printed lines between the circles.

![Image of the portable version of the HSEBT mat](image)

**Figure 3** The portable version of the HSEBT mat

According to the measurement standards of the HSEBT complementary anthropometrics for each participant were recorded before testing. Length of extremities might contribute to longer reach distance and therefore these measurements are part of the standard procedure (30). Wingspan, leg length and arm length and were measured in centimeters and done with a standard tape measure. Wingspan was measured from middle digit to middle digit with both shoulders abducted to 90°, leg length was measured from the greater trochanter to the bottom of the lateral malleolus and arm length was measured from acromion to middle digit with shoulder abducted to 90° of one arm.
The Oslo sports trauma research center overuse injury questionnaire (OSTRC)

The Swedish version of the validated self-reported questionnaire OSTRC was used to report the prevalence and severity of overuse for all participants in this study (16, 27). All subjects were instructed to answer the questionnaire and the chosen body regions were the shoulder, hip, knee, foot and lower back. The responses of the questionnaire were analysed and interpreted primarily to the method developed by Clarsen, Myklebust and Bahr (27).

<table>
<thead>
<tr>
<th>The Oslo sports trauma research center overuse injury questionnaire&quot; (OSTRC)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body regions:</strong> Shoulder, Lower back, Hip, knee, foot</td>
</tr>
<tr>
<td>Please answer all questions regardless of whether or not you have problems. Select the alternative that is most appropriate for you. The term “problems” refers to pain, ache, stiffness, swelling, instability, locking or other complaints.</td>
</tr>
</tbody>
</table>

**Question 1:** Have you had any difficulties participating in normal training and competition due to ...... problems during the past week?
- Full participation without problems... (0 points)
- Full participation but with problems... (8 points)
- Reduced participation due to problems... (17 points)
- Cannot participate due to problems.... (25 points)

**Question 2:** To what extent have you reduced your training volume due to .... problems during the last week?
- No reduction (0 points)
- To a minor extent (6 points)
- To a moderate extent (13 points)
- To a major extent (19 points)
- Cannot participate at all (25 points)

**Question 3:** To what extent have your problems affected your performance during the last week?
- No effect (0 points)
- To a minor extent (6 points)
- To a moderate extent (13 points)
- To a major extent (19)
- Cannot participate at all (25 points)

**Question 4:** To what extent have you experienced pain related to your sport during the past week?
- No pain (0 points)
- Mild pain (8 points)
- Moderate pain (17 points)
- Severe pain (25 points)
The responses of each question were summed in order to calculate a severity score from 0 to 100 for each body region (shoulder/ back/ hip/ knee/ foot). The response values were allocated numerical value where 0 represents no problems and 25 represents the maximum level. In order to maintain an even distribution from 0 to 25 the values for intermediate responses were set to 0-8-17-25 for question one and four and 0-6-13-19-25 for questions two and three (figure 4) (27). In addition, a "Total severity score for all body regions" was calculated as the sum of the severity score for each body region, were 500 represents the maximum available points. Figure 5 illustrates the outcomes from the questionnaire.

The prevalence of severe injury was if the person answered any of the last three alternatives of answers (3-5) in question 2 or 3 (marked in yellow Figure 3) for each body region. That is: "To what extent have you reduced your training volume or to what extent has your shoulder/ lower back/ hip/ knee or foot affected your performance. The total numbers of body regions with severe injuries were used in the study and the outcome is described as number of areas with severe injury. (Figure 5).

Data analysis:

The results of the measurements with the HSEBT were collected and plotted for further analyses into a computer program developed by Athletic Knowledge Nordic AB, Stockholm (https://1080map.com). All measurements in centimeters (reach tests 1-16) and degrees (rotational tests 17-20) were calibrated with anthropometric measures and then converted into points when plotted in the program (30). The program provides both a graphic picture as a spider diagram and a presentation of the points for each participant (figure 3).

The normative data were calculated as mean, standard deviation and range for each measure of both HSEBT and OSTRC in Microsoft excel for Mac version 16.24 and presented as normative data. Association between dynamic functional mobility and overuse injuries in the group were made with a correlation analysis. Pearson correlation analysis (two tailed) was used to determine the relationship between the scoring in the HSEBT tests and scoring on the OSTRC. Three parameters from the OSTRC were used for three separate correlation analyses: 1) Severity score from each body region, 2) The total severity score and 3) The number of areas with severe injury (figure 5). The strength of the correlation coefficient (r)
were used in the analyses. The relationship of the included parameters as described with the value of “r” can be either negative or positive and is between +1 and -1. Values over 0.7 indicates a strong uphill relationship, values between 0.50-0.69 indicates moderate correlation, values between 0.26-0.49 indicates weak correlation and values under 0.25 indicates almost no correlation and vice versa for the negative relationships. The significance level was set at p<0.05 (31). The calculations were conducted in SPSS version 25 for Windows for Mac (SPSS Inc North Michigan Avenue, Chicago IL, 60611).

Figure 5. Flow Chart over including analyzed parameters in the questionnaire OSTRC, the yellow boxes highlights outcomes used in the correlation analysis.
Results

Characteristics

A total of 31 participants were included in the study. The personal characteristics of the participants are presented in Table 1.

Table 1. Baseline characteristics of the study population (N=31)

<table>
<thead>
<tr>
<th>Personal characteristics</th>
<th>Mean</th>
<th>SD*</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>17</td>
<td>1</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>57,8</td>
<td>6,8</td>
<td>75</td>
<td>42</td>
</tr>
<tr>
<td>Length, cm</td>
<td>169,4</td>
<td>6,8</td>
<td>182</td>
<td>151</td>
</tr>
<tr>
<td>Age of sport specialization</td>
<td>8,5</td>
<td>2,8</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>Training hours/week, hours</td>
<td>13,9</td>
<td>4,7</td>
<td>23</td>
<td>6</td>
</tr>
<tr>
<td>Training hours last 7 days, hours</td>
<td>13,2</td>
<td>4,7</td>
<td>23</td>
<td>5</td>
</tr>
</tbody>
</table>

* SD=Standard deviation
Normative data of dynamic functional mobility (HSEBT)

The results of all 20 tests are presented in Table 2 in test order where the left foot is tested before the right. On average the group has very high scores which means that they reached and rotated far out on the mat. Although the range in the group presents outliers in dynamic functional mobility with low and/or asymmetrical scores. In the last column the average profile from Eriksruds study is presented to give a reference as it is the only study with reference values of all twenty tests.

Table 2. Descriptive statistics of the Hand reach star excursion balance test (HSEBT) in points (test 1-16) and in degrees (test 17-20) presented as mean (M), standard deviation (SD) and minimum and maximum values.

<table>
<thead>
<tr>
<th>Test order</th>
<th>Test*</th>
<th>Foot</th>
<th>M</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>Ref** (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LR45</td>
<td>L</td>
<td>9,0</td>
<td>0,9</td>
<td>7,1</td>
<td>10,6</td>
<td>8,8</td>
</tr>
<tr>
<td>2</td>
<td>RL45</td>
<td>R</td>
<td>9,1</td>
<td>0,9</td>
<td>7,1</td>
<td>10,6</td>
<td>8,9</td>
</tr>
<tr>
<td>3</td>
<td>LA0</td>
<td>L</td>
<td>8,6</td>
<td>0,8</td>
<td>7,2</td>
<td>10,3</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>RA0</td>
<td>R</td>
<td>8,6</td>
<td>0,9</td>
<td>7,2</td>
<td>10,3</td>
<td>8,1</td>
</tr>
<tr>
<td>5</td>
<td>LL45</td>
<td>L</td>
<td>8,1</td>
<td>0,7</td>
<td>6,3</td>
<td>9,5</td>
<td>7,3</td>
</tr>
<tr>
<td>6</td>
<td>RR45</td>
<td>R</td>
<td>8,2</td>
<td>1,1</td>
<td>4,8</td>
<td>9,8</td>
<td>7,3</td>
</tr>
<tr>
<td>7</td>
<td>LL90</td>
<td>L</td>
<td>8,8</td>
<td>1</td>
<td>6,9</td>
<td>10,3</td>
<td>8,1</td>
</tr>
<tr>
<td>8</td>
<td>RR90</td>
<td>R</td>
<td>9,3</td>
<td>0,8</td>
<td>7,8</td>
<td>11,6</td>
<td>8,1</td>
</tr>
<tr>
<td>9</td>
<td>LR90</td>
<td>L</td>
<td>9,5</td>
<td>0,7</td>
<td>8,2</td>
<td>11,8</td>
<td>7,6</td>
</tr>
<tr>
<td>10</td>
<td>RL90</td>
<td>R</td>
<td>9,3</td>
<td>0,7</td>
<td>7,1</td>
<td>10,8</td>
<td>7,6</td>
</tr>
<tr>
<td>11</td>
<td>LL135</td>
<td>L</td>
<td>9,6</td>
<td>0,7</td>
<td>8,3</td>
<td>11,2</td>
<td>8,9</td>
</tr>
<tr>
<td>12</td>
<td>RR135</td>
<td>R</td>
<td>9,1</td>
<td>1,1</td>
<td>6,1</td>
<td>11,3</td>
<td>8,9</td>
</tr>
<tr>
<td>13</td>
<td>LP180</td>
<td>L</td>
<td>9,0</td>
<td>1</td>
<td>7,4</td>
<td>11,2</td>
<td>7,6</td>
</tr>
<tr>
<td>14</td>
<td>RP180</td>
<td>R</td>
<td>9,0</td>
<td>1</td>
<td>7,5</td>
<td>11,2</td>
<td>7,4</td>
</tr>
<tr>
<td>15</td>
<td>LR135</td>
<td>L</td>
<td>6,8</td>
<td>1,5</td>
<td>4,5</td>
<td>10,4</td>
<td>5,6</td>
</tr>
<tr>
<td>16</td>
<td>RL135</td>
<td>R</td>
<td>7,3</td>
<td>1,4</td>
<td>3,8</td>
<td>9,7</td>
<td>5,6</td>
</tr>
<tr>
<td>17</td>
<td>LRrot</td>
<td>L</td>
<td>118</td>
<td>17,2</td>
<td>65</td>
<td>145</td>
<td>129</td>
</tr>
<tr>
<td>18</td>
<td>LLrot</td>
<td>R</td>
<td>115</td>
<td>15,6</td>
<td>75</td>
<td>135</td>
<td>124</td>
</tr>
<tr>
<td>19</td>
<td>RLrot</td>
<td>L</td>
<td>123</td>
<td>13,1</td>
<td>90</td>
<td>142</td>
<td>134</td>
</tr>
<tr>
<td>20</td>
<td>RRrot</td>
<td>R</td>
<td>112</td>
<td>16,9</td>
<td>75</td>
<td>114</td>
<td>119</td>
</tr>
</tbody>
</table>

* L and R is prefix for left and right leg
** Ref is the reference values from Eriksrud et al 2017.

Test nr 1-6 (Table 2) contains tests in a flexion pattern and are overall very high scores (highlighted in green). Slightly lower scores are seen in test nr 5 and 6 in a pattern of flexion,
internal rotation, adduction of the hip, dorsiflexion and supination of the foot compared to the flexion pattern with abduction and external rotation.

Test nr 7-10 (Table 2) are tests of lateral flexion pattern (blue) and these tests are mainly performed in the frontal plane as a "reach to the side". The participants shows lower scores on lateral flexion to the left (LL90, RL 90).

Test nr 11-16 (Table 2) are tests in an extension pattern (orange) where you are instructed to reach backwards in the same synergies as in the flexion pattern. The overall lowest scores is found when the hip is extension, internal rotation, adduction and the foot is in dorsiflexion and supination (LR135, RL135).

Test nr 17-20 (Table 2) (marked in yellow) is rotational tests where the individuals first rotate to the right (on left leg) which produces a rotational pattern of external rotation of the hip and pronation of the foot (LRrot). These test are the most limited in the group.
Prevalence of ongoing overuse injuries (OSTRC)

All athletes answered the questionnaire. All athletes except one (30 out of 31) reported an ongoing overuse injury and most frequent symptoms were reported in the hip, lower back and knee. The participants reported on average overuse injuries in 2.4 out of 5 body regions (Figure 6).

![Figure 6. Prevalence of overuse syndromes in each body region in the group (N=30)](image)

Severity score for each body region

The highest average severity scores were seen in the lumbar spine and knee whereas the hip and foot have a high range in scoring with the highest severity scores in the group (Table 3).

| Table 3. Descriptive statistics of the Severity score of body regions in the OSTRC |
|-----------------------------------------------|-----|-----|----------------|
| Severity score shoulder (0-100)             | 9   | 17  | 0-61           |
| Severity score hip (0-100)                   | 12  | 18  | 0-80           |
| Severity score knee (0-100)                  | 17  | 22  | 0-72           |
| Severity score foot (0-100)                  | 16  | 22  | 0-74           |
| Severity score lumbar spine (0-100)          | 18  | 22  | 0-63           |
| Total severity score for all body regions (0-500) | 71  | 38  | 0-80           |

Total severity score

The total severity score represents the sum of severity score for all body regions and could be 500 points in theory. Such a high value was not seen in the group since not all participants
had a scoring of overuse in each body region. (Table 3). In Figure 7 the sum of severity scores in all five body region is presented as a *total severity score* for each participant.

**Figure 7.** Total Severity score for each participant

**Severe overuse injury**

67% "severe overuse injury were present in the group. *Severe injury* was substantial problems in training volume or training performance (Figure 4, highlighted in yellow). Substantial problem was defined as an overuse problem causing moderate to severe reductions in training volume or training performance or complete inability to participate in training or competition. The distribution of number of severe injuries in each body region are presented in Table 4 which shows that the knee has the most severe injuries (26%) followed by the foot (23%) and lower back (20%).

**Table 4.** Number of severe or not severe injury in the five body regions

<table>
<thead>
<tr>
<th></th>
<th>Shoulder n (%)</th>
<th>Lower back n (%)</th>
<th>Hip n (%)</th>
<th>Knee n (%)</th>
<th>Foot n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe injury</td>
<td>2 (6%)</td>
<td>7 (20%)</td>
<td>3 (10%)</td>
<td>8 (26%)</td>
<td>7 (23%)</td>
</tr>
<tr>
<td>Not severe injury</td>
<td>29 (94%)</td>
<td>24 (80%)</td>
<td>28 (90%)</td>
<td>23 (74%)</td>
<td>24 (77%)</td>
</tr>
</tbody>
</table>
Association between dynamic functional mobility and overuse injuries

A higher severity score for the lower back was associated with test nr 20 (RRrot) with a correlation coefficient of -0.417 (p=0.02) (Table 5). This test includes dynamic functional mobility in a rotational pattern that elicits right rotation in the trunk, internal rotation in the hip and knee and supination of the foot.

In the hip a higher severity score was correlated with test nr 8 (RR90) with a correlation coefficient of 0.497 (p=0.004) and test nr 9 (LR90) with a correlation coefficient of 0.481 (p=0.006) (Table 5). These tests are reach tests in the lateral flexion pattern: both tests contain trunk lateral flexion to the right. Test nr 8 is standing on right leg performing lateral flexion of trunk to the right while the hip goes in abduction and foot in pronation. Test nr 9 is when standing on left leg the trunk lateral flex to the right while the hip goes into adduction and foot in supination. A positive correlation were seen which means that the participants who had higher scorings (a longer reach possibility) had higher severity score.

The total severity score were correlated with extension patterns standing on the left leg with a negative correlation coefficient of -0.364 (test nr 11) (LL135; P=0.04) and test nr 13 (LP180) had a negative correlation coefficient of -0.375 (P=0.04) (Table 5).

No significant associations between the performance on HSEBT and the number of areas with severe injury was found.

**Table 5. Significant associations in the correlation analysis**

<table>
<thead>
<tr>
<th>OSTRC</th>
<th>HSEBT</th>
<th>Correlation coefficient</th>
<th>Significance p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severity Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower back (prevalence of severe injury)</td>
<td>RRrot</td>
<td>-0.417</td>
<td>0.02</td>
</tr>
<tr>
<td>Severity score Hip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RR90</td>
<td>0.497</td>
<td></td>
<td>0.004</td>
</tr>
<tr>
<td>LR90</td>
<td>0.481</td>
<td></td>
<td>0.006</td>
</tr>
<tr>
<td>Total severity score (sum of several regions with severe injury)</td>
<td>LL135</td>
<td>-0.364</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>LP180</td>
<td>-0.375</td>
<td>0.04</td>
</tr>
</tbody>
</table>
Discussion

Main results

To our knowledge, this is the first study aiming to establish normative data for female elite team gymnasts with the HSEBT and to record overuse injuries with the OSTRC. Another aim was to evaluate if there was an association between dynamic functional mobility and ongoing overuse injuries in the group. The results of this study showed that this group reached very far on the test mat in most of the test directions, however, the range indicated certain heterogeneity within the tests. The total prevalence of injuries in the group was very high since almost all participants reported an ongoing injury. Prevalence of severe injury in the lower back was associated with lower scoring on the right leg in a rotational movement pattern (test 20) whereas prevalence of severe injury in the hip was associated with extreme high mobility in a sidebending pattern in both legs (test 8, 9). There was also a relationship between individuals with multiple severe overuse injuries and dynamic functional mobility in an extended movement pattern of the left leg (test 11, 13).

Results of the HSEBT

An interesting finding in this study was the very restricted or limited dynamic functional mobility in some individuals in the rotational tests (15-20). A high mobility in gymnasts might have been expected and therefore it was surprising to see that the rotational tests was even lower in the gymnasts than in Eriksruds et als. study of recreationally active healthy men (3). The gymnasts had lower scores in all four rotational test containing rotation of the extremity in either a coupled motion in supination of the foot and internal rotation of the hip or in a coupled motion of pronation of the foot and external rotation of the hip. In these tests the hip and the foot should contribute to a lot of movement and at the same time the load of the lumbar spine should be appropriate due to capability of distributing the load throughout the kinetic chain (15, 21, 24).

The limited scorings in certain individuals in the extension patterns (test 11, 13) are movement patterns that demands most balance of all tests. These tests elicits extension of the back in a coupled motion with hip extension, internal rotation and adduction in the hip. If the mobility of the hip is limited, it could be possible that the lumbar spine have to
compensate for that. Earlier studies concerning back problems in the gymnastic population have focused on examination and training of the lower back and mostly in lying (19). Since the demand on a gymnasts back include repetitive flexion and extension with high loads during landing, vaulting and somersaults etc. it is relevant to give the back a lot of focus. The HSEBT gives us an additional opportunity to see if the individual can take out the mobility in the whole kinetic chain and to distribute the load in for example the spine in an appropriate way and have sufficient mobility in the hip (19). Conclusions of limited mobility, stability and the effect of the kinetic chain in this group is beyond the scope of this article but the example highlights the clinical benefit with the instrument compared to traditional ways of directing assessment to only areas with symptoms (19). This study could highlight the need to further study the kinetic chain and for example the role of mobility in the hip for the lower back (19, 21, 32).

Results of the OSTRC

The report of overuse injuries in the group was high (97%), even higher than in existing literature of overuse injuries among adolescents as well as in gymnasts (19-21, 33, 34). When the overuse injuries in this group were further analysed there were in total 67% of body regions that had a severe overuse injury (table 4). An advantage of using the OSTRC could be the possibility to further analyse the extent as well as the consequences of overuse injury (27). Since elite training often are associated with symptoms as for example muscle soreness or tiredness the method to sort out minor problems can be of clear advantage in the clinical setting. The possibility to determine severity could also be useful as the exact onset of an overuse injury has been described as hard to define (34). Many athletes and especially gymnasts also seems to train despite ongoing injury. Previous studies have reported the lower back and lower extremities as most common injury regions among gymnasts (19, 35). A previous injury have been described as one of the biggest risk factor for a new injury to occur and it can therefore be motivated to include self reporting methods of ongoing symptoms in injury registration. In this study 53% of the participants reported an ongoing injury in the back of which 20% were severe injuries affecting participation in the sport although these individuals were still training at a high level. All the gymnasts in this study were training at least 6 hours/week with an average training time of 13,9 hours per week, with some individuals training over 20 hours/week. Potentional reasons for the high prevalence of overuse injuries in this group could of course be related to the high volume of training/week.
Overuse injuries have a clear association with high training load and intensity according to the literature (32-36). When it comes to overuse injuries in the lumbar spine, training over 6 hours/week have shown to increase the prevalence of back problems (36). Since 6 hours training/week is far under normal training frequency/week in the gymnastic population the capability to both tolerate and distribute load is of importance. Therefore it seemed interesting to study if athletes with symptoms of overuse have lower scores in dynamic functional mobility and how they use their movement pattern. In this study almost all participants had several ongoing injuries at the same time they were extremely mobile according to the instrument HSEBT. Conclusions about associations between limited dynamic functional mobility and overuse injury were therefore not obvious on group level. This is also in line with previous studies were there have been difficulties to associate certain impairments with certain injuries (4, 5, 37). Recommendations in the literature is therefore instead to determine normative values for the most reliable and valid functional tests in the youth population at the same time create consistent terminology and definition of both injuries, injury registration as well as test procedures (5). Injury registration among team gymnasts have not yet been described as a standard (38). In team gymnastics in Sweden a new form of weekly injury registration has been proposed and are under development through an application in the mobile phone (39).

Method HSEBT
The HSEBT is described as a reliable and valid instrument. Test-retest reliability has been described as moderate to high and inter-rater reliability as high (3). The validity of the test have been studied in the same study by Eriksrud 2017 were the tests have been performed with reflective markers and recorded by camera. Analysis of validity have also been made by comparing all of the reach tests with the rotational tests using linear regression analysis and the Bland Altman method. Although the reach and rotational test is rather different, since the first mentioned is affected by gravity and the others not, a good to excellent relationship between these measurements have been shown (3). Many of todays screening tests elicits only movements in the sagittal plane or tests for the lower extremity contains sagittal plane movements while for example rotation which is a horizontal plane movement is tested in the upper extremity (5, 9, 11). A valid screening of movement might start with considering how normal movement is conducted although not in the scope of this article.
A problem with the quantifying of movement according to the HSEBT could be the multiple confounders. The measurements could possibly be affected by time of the day, learning effects and if the individual performs its maximum in reaching or not. Pain, tiredness is other clear confounders. In Eriksruds studie there were no effect on time of the day nor were there any learning effect between test sessions (3). In this study every test was performed three times as recommended and the best measurement out of three were used. A possibility to calculate the mean value of the three tests might have changed the results a bit. In Eriksruds studie it was interesting to see that when his subjects could see the reach measurements (how far they scored) a lower variation in scoring were observed (3).

In this study the calculations and analyses were used according to how the instrument are supposed to be used as explained in the user manual (https://1080map.com). This means that all included measures in centimeters have been converted into points and calibrated with anthropometric measures before being analysed. This is not in line with earlier studies on the instrument where the raw data were used in all calculations (3, 15, 40). If an aim is to conduct studies with appropriate and homogenous design it might be useful to have recommendations for the most appropriate data collection in the manual. The possibility to calibrate the measurements with anthropometric measures might strengthen the study quality if we know that arm length for example could affect the tests. When conducting this study no such studies were yet know. One problem with the HSEBT is that this test system does not clearly describe how the calibrations with anthropometric measures are done and how the scores are converted from centimeters to points. There is no maximum value specified for the tests but the size of the mat gives a maximum value of around 11 points and it is not possible to rotate more than a circle. A discussion with the constructor of the test has been made but since research on influences of anthropometrics were on its way to be published no further information were given during the conduction of this study (22).

Method- OSTRC

The construct of overuse injuries has been described to be captured with the OSTRC (16). It has also been described as more relevant in research concerning overuse injuries and has identified more than 10 times as many cases with injury than standard methods of injury registration were time loss has been the outcome. Clarsen et al reports in their study that 75% of their study population were identified with an overuse injury compared to 11% with
standard injury registration during a 3-months study period (27). Ekman et al also found that several athletes trained and competed with overuse injuries even though their study focused on the validity of the instrument (16). This highlights again the magnitude of overuse injuries and the fact that athletes train with ongoing injuries but also that these outcome measurements evaluates totally different aspects of injuries (27, 41). Limitations with this method could be the fact that self-assessments of pain and sports participation is a subjective method. It might be argued that comparisons between individuals is not valid since individuals might score different depending on mood, stress, memory etc. This could be solved if the subjects had answered the questionnaire several times. Another shortcoming is that this questionnaire does not give any detailed information about the injury. This could be valuable if the questionnaire should be used in the clinical setting. Complementary questions as well as examinations by a physiotherapist is therefore recommended (27).

Method correlation analysis

When looking for associations with overuse injuries some correlations were seen although the interpretation of the result has to be analyzed with its limitations in study design for example a relatively small sample size, and that the group was only tested once (37). All twenty tests were correlated against the severity score of each body regions as well as number of body regions with severe injury and then the total severity score. The Pearson's r-correlation was used to determine the strength of the correlation coefficient (37).

Conclusion

Assessment of dynamic functional mobility aims to capture neuromuscular control involved in movements and can give more information of deficits in the kinetic chain than conventional tests of single components of movement. Normative data of dynamic functional mobility according to the HSEBT can provide clinicians with reference points to compare elite female team gymnasts. Although the individual movement analysis might tell us more than comparisons of movement patterns on group level. Clinical usable methods in this field that can be incorporated in the musculoskeletal assessment needs to be highlighted and physiotherapists need to be part of the development of new methods. The result of this study showed that gymnasts trained with a high prevalence of ongoing overuse injuries. Since all individuals have different movement strategies, as well as they can be affected by an ongoing overuse injury, a possibility to quantify a full kinetic chain movement can be of importance.
Further research is needed to continue the process of establishing normative data in different group of athletes.
Declarations
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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author.

Competing interests
The authors declare that they have no competing interests.

Consent for publication
Not applicable.

Ethics approval and consent to participate
The study was approved by the local ethical group at Luleå University of Technology, Division of Health Sciences, in November 2017 (dnr: LTU-325-2018). All participants signed a written consent form prior to their participation.

Authors' contribution
Not applicable.

Author information
Not applicable.
References


Information och förfrågan om medverkan i examensarbete


För att kunna delta i studien är du kvinna mellan 16 och 19 år. Du tränar mellan 5-15 timmar/vecka inom din idrott. Du bör ej ha haft någon allvarligare skada såsom fraktur, trasigt ledband, hjärnskakning eller genomgått någon operation de senaste tre månaderna. Studien innehåller två delar:
1) Ett frågeformulär som innehåller frågor om tidigare eller nuvarande överbelastningsbesvär. Formuläret skickas ut via mail som en webbenkät om medverkan i studien godkänts.

testens genomförande. På detta sätt garanteras att uppgifter om dina resultat behandlas helt anonymt.

Kontaktuppgifter och frågor om studien: Handledare
Åsa Bocké, Legitimerad Fysioterapeut : Inger Jacobson
sabocx-4@student.ltu.se inger.jacobson@ltu.se
076-3111369 0920-49 10 00
Informerat samtycke

Jag och målsman (om du är under 18 år) har läst informationsbrevet ovan och godkänner medverkan i projektet genom att **kopiera denna text samt fylla i kontaktuppgifter och returnera/mail till sabocx-4@student.ltu.se.**

På detta sätt tackar jag ja till att fylla i en enkät om överbelastningsskador samt genomgå ett rörlighetstest som ovan beskrivet. Då du skickat in detta kommer du inom 1-3 veckor erhålla en webbenkät och via mail från mig bli erbjuden tid för test.

**Namn:**

**E-mailadress:**

**Telefonnummer:**
Frågeformulär
Detta frågeformulär fylls i innan deltagande i rörelsescreningen HSEBT

Namn: ........................................................................................................................................

Ålder och födelseår: ...............................................................................................................

Vikt i kg: ................................................................................................................................

Längd i cm: ...........................................................................................................................

Höger/vänsterhänt: .............................................................................................................

Hur många år har du tränat gymnastik: ..............................................................................

Har du fler sporster, isåfall vilken: ..................................................................................

Om du har övergått till att enbart träna gymnastik i vilken ålder gjorde du detta? ....

Hur många timmar träna du i genomsnitt varje vecka: .....................................................

Ange hur många timmar du sammanlagt har tränat de senaste 7 dagarna
Avrunda till närmaste timme: ............................................................................................

Ange hur många timmar du tävlat de senaste 7 dagarna
Avrunda till närmaste timme: ............................................................................................

Ange tidigare skador som påverkat ditt idrottande: ..........................................................
OSTRC- Overuse Injury Questionnaire
Svenskt översatt formulär för självskattning av överbelastningsskada.
Formuläret innehåller 4 frågor/ kroppsdel, svara på samtliga frågor genom att välja det bäst lämpade svarsalternativet. Då du svarar på frågorna om respektive kroppsdel utgå från hur det varit de senaste 7 dagarna.

Skulderproblem
Med skulderproblem menas smärta, värk, stelhet, överrörlighet eller andra problem i axel och skuldra.
Har du problem med att delta i din idrott (ordinarie träning/match/tävling) på grund av dina skulderproblem?
   o Deltar för fullt, utan problem
   o Deltar för fullt, men med problem
   o Minskat deltagande, på grund av problem
   o Kan ej delta, på grund av knäproblem

I vilken grad har du minskat på träningsmängden på grund av dina skulderproblem?
   o Ingen minskning
   o I liten grad
   o I måttlig grad
   o I stor grad
   o Kan ej delta

I vilken grad upplever du att dina skulderproblem påverkat idrottsprestationen?
   o Ingen påverkan
   o I liten grad
   o I måttlig grad
   o I stor grad
   o Kan ej delta

I vilken grad upplever du smärta i skuldran under ditt idrottsutövande?
   o Ingen smärta
   o I liten grad
   o I måttlig grad
   o I stor grad
Höftproblem
Med höftproblem menas smärta, värk, stelhetskänsla, eller andra problem i höften och låret. Har du problem med att delta i din idrott (ordinarie träning/match/tävling) på grund av dina höftproblem?

- Deltar för fullt, utan problem
- Deltar för fullt, men med problem
- Minskat deltagande, på grund av problem
- Kan ej delta, på grund av knäproblem

I vilken grad har du minskat på träningsmängden på grund av dina höftproblem

- Ingen minskning
- I liten grad
- I måttlig grad
- I stor grad
- Kan ej delta

I vilken grad upplever du att dina höftproblem påverkat idrottsprestationen?

- Ingen påverkan
- I liten grad
- I måttlig grad
- I stor grad
- Kan ej delta

I vilken grad upplever du smärta i din höft eller i låret under ditt idrottsutövande?

- Ingen smärta
- I liten grad
- I måttlig grad
- I stor grad

Knäproblem
Med knäproblem menas smärta, värk, stelhet, instabilitet, svullnad, låsningar eller andra problem i knäet.

Har du problem med att delta i din idrott (ordinarie träning/match/tävling) på grund av dina knäproblem?

- Deltar för fullt, utan problem
o Deltar för fullt, men med problem
o Minskat deltagande, på grund av problem
o Kan ej delta, på grund av knäproblem

I vilken grad har du minskat på träningstid på grund av dina knäproblem?

o Ingen minskning
o I liten grad
o I måttlig grad
o I stor grad
o Kan ej delta

I vilken grad upplever du att dina knäproblem påverkat idrottsprestationen?

o Ingen påverkan
o I liten grad
o I måttlig grad
o I stor grad
o Kan ej delta

I vilken grad upplever du smärta i ditt knä under ditt idrottsutövande?

o Ingen smärta
o I liten grad
o I måttlig grad
o I stor grad

Fot-/underbensproblem
Med fot-/underbensproblem menas smärta, värk, instabilitet eller andra problem i foten/underbenet.
Har du problem med att delta i din idrott (ordinarieföra, match/tävling) på grund av dina fot-/underbensproblem?

o Deltar för fullt, utan problem
o Deltar för fullt, men med problem
- Minskat deltagande, på grund av problem
- Kan ej delta, på grund av knäproblem

I vilken grad har du minskat på träningstemperatur på grund av dina fot/underbensproblem?
- Ingen minskning
- I liten grad
- I måttlig grad
- I stor grad
- Kan ej delta

I vilken grad upplever du att dina fot-/underbensproblem påverkat idrottsprestationen?
- Ingen påverkan
- I liten grad
- I måttlig grad
- I stor grad
- Kan ej delta

I vilken grad upplever du smärta i din fot/underben under ditt idrottsutövande?
- Ingen smärta
- I liten grad
- I måttlig grad
- I stor grad

**Ländryggsproblem**
_Med ländryggsproblem menas smärta, värk, stelhet eller andra problem i ländryggen._

Har du problem med att delta i din idrott (ordinarie träning/match/tävling) på grund av ditt ländryggsproblem?
- Deltar för fullt, utan problem
- Deltar för fullt, men med problem
- Minskat deltagande, på grund av problem
- Kan ej delta, på grund av knäproblem
I vilken grad har du minskat på träningsmängden på grund av dina ländryggsproblem?

- Ingen minskning
- I liten grad
- I måttlig grad
- I stor grad
- Kan ej delta

I vilken grad upplever du att dina ländryggsproblem påverkat idrottsprestationen?

- Ingen påverkan
- I liten grad
- I måttlig grad
- I stor grad
- Kan ej delta

I vilken grad upplever du smärta i din ländrygg under ditt idrottsutövande?

- Ingen smärta
- I liten grad
- I måttlig grad
- I stor grad