Abstract

Purpose: The purpose of this study is to compare the flexibility of high school baseball players’ LBP Group and bilateral lower extremity muscles.

Method: This study conducted a questionnaire survey and measurement of muscle flexibility targeting 23 high school baseball players in Korea. The questionnaire consisted of 7 items on basic information and 4 items on past and present back pain, and muscle flexibility measurement (Tomas test, Hip extension, HBD, SLR, Trunk rotation) tests were conducted. As for the data processing of this study, the mean and standard deviation of all questions were calculated by using the SPSS 26.0 package. The two-way ANOVA was performed to examine the effect of each measurement according to the LBP Group (LBP; presence or absence) × both sides (dominant, non-dominant), and if an interaction was found, the post hoc test was conducted. The independent sample t-test and paired t-test were performed for the post hoc verification. The statistical significance level was based on p<.05.

Results: As a result of the Thomas test conducted for the LBP Group and both sides of the lower extremity muscle flexibility, the both sides of the main effect turned out to be significant [F(1,21)=4.905, p<.05]. In the case of the hip extension, the main effect of both sides turned out to be significant [F(1,21)=6.768, p<.05], and the main effect of the LBP Group also turned out to be significant [F[(1,21)=5.065, p<.05]. Furthermore, in the case of the SLR, the main effect of the LBP Group turned out to be significant [F(1,21)=5.395, p<.05].

Conclusion: Gathering the results above, as a cause of the LBP among the high school baseball players, there is a possibility that a decrease in flexibility due to hip flexion and extensor tension may be induced, and hence, the possibility of inducing LBP was confirmed due to the excessive use of the back muscles of the accelerator during the pitching and hitting sections. In the future studies, it is necessary to develop and apply the programs which can prevent and rehabilitate the LBP.

Keywords: High School Baseball Player, LBP, ROM, Lower Extremity Muscle Flexibility, Dominant and Non-Dominant

1. Introduction

Low back pain (LBP) occurs frequently among young adult players[1], and the LBP at this point in time is highly likely to be caused by structural problems as well as non-structural problems[2]. For this reason, 3 factors were primarily reported in the previous studies. First, given the rapid bone growth in the growth phase, bones become weak, and since the muscles and ligaments cannot keep up with the bone growth and development, an imbalance in the decrease in the muscle’s flexibility occurs[3][4]. Second, the amount, intensity, and duration of training may be noted. Since this period is one of regular and continuous training, overuse often causes LBP such as spondylolysis, a stress fracture of the lumbar spine[5]. Lastly, there is the specificity of sports events. Because each sport requires a different type of movement, the incidence and prevalence of LBP varies. In a previous study, LBP among young adults generally occurred in 10%
to 15% of the total, and among the sports athletes, it was reported that 37.5% in baseball, 48.6% in athletics, and 50 to 86% in gymnastics were reported to rise. According to a report on the survey, the highest incidence rate is in the order of shoulder (27%), elbow (23%), and waist (21%). As such, LBP is an important disease that ought not to be overlooked among young adult baseball players\[6\][7].

Baseball is a sport which is consisted of throwing, hitting, and defending movements and is also a sport which repeats movements in the same direction, and it is also reported that the repetition of such movements causes an imbalance in the trunk muscles, which causes LBP\[8\][9]. Furthermore, it is known that the difference in flexibility of the left and right muscles of the dominant side and the non-dominant side is a factor that causes LBP\[10\][11].

Examining the baseball and LBP related studies, the history of LBP affects the pelvis and lumbar kinematics during the baseball hit, and it also has a relationship with the lumbar flexion angle and angular velocity throughout the bat swing\[12\][13]. The school aged athletes experience LBP due to unhealthy lifestyles such as late bedtime, short sleep times, and long video games, which contribute to the LBP induced lifestyle related diseases\[14\]. Youth baseball players suffer from LBP and knee pain, and the cause of such pain is the elbow and shoulder pain caused by excessive training during their childhood\[15\]. The prevalence of LBP among the young athletes participating in various types of sports varies according to age, gender, and sports field, and to prevent such LBP, it is necessary to develop a diagnosis and rehabilitation program\[16\]. The diagnosis program requires medical examinations including medical check, physical examination, and MRI, and the rehabilitation program is applied based on such diagnostic results\[17\]. In a study related to back injuries among the high school baseball players, the horizontal adduction caused by overtraining on the dominant side was an independent risk factor for the back injuries during the season, and the limitation of shoulder function not only causes shoulder and elbow injuries, but also the risk of back injuries\[18\]. In particular, a lot of LBP is induced by the pitchers during baseball positions, and trunk stability is important to alleviate this LBP. Furthermore, a core stability evaluation method should be developed and applied\[19\]. As a result of investigating the non-specific LBP of college athletes, it turned out that there was a close relationship with core function, and most of the college students had low core function. Hence, it is necessary to strengthen the core muscles in order to prevent injuries in athletes. It is also an important factor in increasing the endurance and appropriate proportions of extensors and flexors\[20\].

According to a previous study conducted on the flexibility of the LBP and lower limb muscles, those with LBP had shorter hamstrings, lowered SLR (Straight Leg Raising) angle, left-right difference, and lower fingertip-to-floor distance (FFD), and the flexibility of the lower extremities falls during the growth period. That is, as the flexibility of the lower extremities is lowered, there is a possibility that the movements of the pelvis and lumbar spine may change, which is highly likely to be a factor causing LBP\[21\]. As a result of evaluating the differences between subjects who experienced mild mechanical LBP, it was reported that hamstring flexibility and tension have a strong relationship with LBP\[22\][23]. Furthermore, a state-of-the-art medical device is required for the diagnosis and treatment of LBP among the sports athletes, but since these medical devices are too expensive, it is necessary to develop a simple and easy way to measure and evaluate\[17\][24].

However, the studies examining the relationship between LBP and lower extremity muscle flexibility among youth adult sports athletes are inadequate\[1\]. Hence, the purpose of this study is to compare and analyze the differences in terms of the flexibility of the lower extremity muscles according to the LBP and dominant and non-dominant among high school baseball players.
2. Research Method

2.1. Participants

This study was conducted for 23 Korean high school baseball players, and the purpose, method, and risks of the study were explained to the subjects, coaches, and parents in writing and verbally in advance, and written consent was secured. Furthermore, this study was conducted with the approval of the Research Ethics Committee of Tsukuba University (Approval Number 28-64). The characteristics of the participants are as illustrated in Table 1.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall (n=23)</th>
<th>LBP (n=15)</th>
<th>Non-LBP (n=8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>17.00±0.91</td>
<td>17.17±0.88</td>
<td>16.88±0.99</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>176.55±5.96</td>
<td>176.71±5.54</td>
<td>176.30±7.07</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>79.38±10.95</td>
<td>81.19±11.34</td>
<td>75.99±9.95</td>
</tr>
<tr>
<td>BMI (kg/m^2)</td>
<td>25.47±3.46</td>
<td>26.17±3.99</td>
<td>24.35±1.86</td>
</tr>
<tr>
<td>Baseball Career (years)</td>
<td>5.63±1.92</td>
<td>5.37±1.45</td>
<td>6.11±2.65</td>
</tr>
</tbody>
</table>

Note: All values are mean ± standard deviation. LBP: low back pain, BMI: body mass index.

2.2. Questionnaire survey on low back pain

The questionnaire was distributed and completed in October, which is the off-season period. After securing the permission to participate in the research in advance, they visited each school and conducted a survey, and since all participants were minors, the purpose of the study and questionnaire questions were explained to help them understand. Seven questions of basic information of the subjects (age, height, weight, baseball career, main position, pitching side, batting side) and four questions of the past and present LBP (point LBP, pain level, pain location, LBP onset timing) were surveyed. Thereafter, based on the results of the questionnaire survey, the subjects were divided into the groups with and without LBP, and the definition of LBP was defined as a case of pain in the lower back (Table 1).

2.3. Measurement of muscle flexibility

The muscle flexibility was measured by a passive test and was photographed by using a digital camera. The range of motion (ROM) and distance (only HBD) were calculated by using the software which analyzes the images based on the secured photos. Furthermore, the data were analyzed by classifying them into a dominant side and a non-dominant side. There are 5 measurements, which are the Thomas test, Hip extension, Heel Buttock Distance (HBD), Straight Leg Raising (SLR), and the Trunk rotation, whose detailed measurement methods are as follows (Figure 1).

2.3.1. Thomas test

The angle of hip flexion was measured from a line parallel to the bed and the long axis of the femur.

2.3.2. Hip extension

The angle between the line parallel to the bed and the long axis of the femur was measured.

2.3.3. HBD

Calibration was performed by attaching a 1m indicator to a vertical line from the ceiling, and the measurement was taken by connecting the maximum protrusion of the heel and buttocks in a straight line.
2.3.4. SLR

The angle between the line parallel to the bed and the long axis of the femur was measured.

2.3.5. Trunk rotation

The angle between the line connecting the acromion of both sides and the horizontal line was measured.

**Figure 1.** Measurement of muscle flexibility.

Note: A: Thomas test, B: Hip extension, C: Heel buttock distance (HBD), D: Straight leg raising (SLR), E: Trunk rotation.

2.4. Statistical analysis

As for the data processing of this study, the mean and standard deviation of all questions were calculated by using SPSS 26.0 (IBM SPSS Statistics for Windows, IBM Corp., Armonk, NY, USA) Package. The two-way ANOVA was performed to examine the effect of each measurement according to the presence or absence of LBP (2) and both sides (2) (dominant, non-dominant), and in the event of an interaction, a post hoc test was performed. As for the post hoc test, the independent sample t-test and the paired sample t-test were performed. The statistical significance level was based on p<.05.

3. Results

In this study, the results of measuring changes in the lower extremity muscle flexibility according to the LBP Group (with and without) and both sides for high school baseball players are illustrated as follows.

3.1. Changes in each metric according to the LBP group and both sides

3.1.1. LBP group and Thomas test for both sides
Table 2. Thomas test results according to LBP group and both sides.

<table>
<thead>
<tr>
<th>Group</th>
<th>Passive thomas test</th>
<th>(Paired sample) t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dominant</td>
<td>Non-dominant</td>
</tr>
<tr>
<td>LBP</td>
<td>23.51±5.28</td>
<td>20.58±5.61</td>
</tr>
<tr>
<td>Non-LBP</td>
<td>22.83±5.40</td>
<td>20.56±6.89</td>
</tr>
<tr>
<td>(Independent sample) t-value</td>
<td>.291</td>
<td>.007</td>
</tr>
</tbody>
</table>

Note: All values are mean ± standard deviation.

The results of the LBP Group and the lower extremity muscle flexibility for both sides of the Thomas test are as illustrated in <Table 2>. In the case of the Thomas test, the main effect of both sides turned out to be significant \[F(1,21)=4.905, p<.05\]. However, the main effect and the interactive effect of the LBP Group were not demonstrated. As a result of the post hoc test of the main effect of both sides, the non-dominant demonstrated a lower trend than the dominant in LBP, yet there was no significant difference demonstrated.

3.1.2. LBP group and hip extension for both sides

Table 3. Hip extension results according to LBP group and both sides.

<table>
<thead>
<tr>
<th>Group</th>
<th>Passive Hip extension</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dominant</td>
<td>Non-Dominant</td>
</tr>
<tr>
<td>LBP</td>
<td>25.51±3.42</td>
<td>28.81±3.55</td>
</tr>
<tr>
<td>Non-LBP</td>
<td>29.75±4.22</td>
<td>30.51±2.72</td>
</tr>
<tr>
<td>t-value</td>
<td>-2.618*</td>
<td>-1.180</td>
</tr>
</tbody>
</table>

Note: All values are mean ± standard deviation, *p<.05, ***p<.001.

The hip extension results of the LBP Group and both sides for the lower extremity muscle flexibility are as illustrated in <Table 3>. In the case of the hip extension, the main effect of both sides turned out to be significant \[F(1,21)=6.768, p<.05\], and the main effect of the LBP Group also turned out to be significant \[F(1,21)=5.065, p<.05\]. However, no interactive effect was demonstrated. As a result of the post hoc test for the main effect of both sides, dominant turned out to be significant \(p<.05\) for the LBP. Furthermore, as a result of the post hoc test conducted for the main effect of the LBP Group, the LBP turned out to be significant \(p<.05\) for dominant than for the non-LBP.

3.1.3. LBP group and HBD for both sides

Table 4. HBD results according to the LBP group and both sides.

<table>
<thead>
<tr>
<th>Group</th>
<th>Passive HBD</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dominant</td>
<td>Non-dominant</td>
</tr>
<tr>
<td>LBP</td>
<td>5.41±3.53</td>
<td>5.38±3.29</td>
</tr>
<tr>
<td>Non-LBP</td>
<td>3.49±2.77</td>
<td>3.48±2.75</td>
</tr>
<tr>
<td>t-value</td>
<td>1.322</td>
<td>1.397</td>
</tr>
</tbody>
</table>

Note: All values are mean ± standard deviation.
The HBD results of the LBP Group and both sides for the lower extremity muscle flexibility are as illustrated in <Table 4>. In the case of the HBD, there was no significant difference demonstrated in terms of the main effect of both sides and the LBP Group, and no significant difference was demonstrated in the interactive effect.

### 3.1.4. LBP group and SLR for both sides

Table 5. SLR results according to the LBP group and both sides.

<table>
<thead>
<tr>
<th>Group</th>
<th>Passive SLR</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dominant</td>
<td>Non-dominant</td>
</tr>
<tr>
<td>LBP</td>
<td>89.13±5.24</td>
<td>91.31±5.77</td>
</tr>
<tr>
<td>Non-LBP</td>
<td>84.94±7.02</td>
<td>84.93±5.71</td>
</tr>
<tr>
<td>t-value</td>
<td>1.624</td>
<td>2.532*</td>
</tr>
</tbody>
</table>

*Note:* All values are mean ± standard deviation, *p<.05.

The SLR results of the LBP Group and both sides for the lower extremity muscle flexibility are as illustrated in <Table 5>. In the case of the SLR, the main effect of the LBP Group turned out to be significant [F(1,21)=5.395, p<.05]. However, the main effect and the interactive effect of both sides were not demonstrated. As a result of the post hoc test on the main effect of the LBP Group, the LBP turned out to be significantly (p<.05) higher for the non-dominant group than for the non-LBP Group.

### 3.1.5. LBP Group and trunk rotation for both sides

Table 6. Trunk rotation results according to the LBP group and both sides.

<table>
<thead>
<tr>
<th>Group</th>
<th>Active trunk rotation</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dominant</td>
<td>Non-dominant</td>
</tr>
<tr>
<td>LBP</td>
<td>41.13±6.72</td>
<td>45.42±5.32</td>
</tr>
<tr>
<td>Non-LBP</td>
<td>44.45±10.26</td>
<td>44.65±7.75</td>
</tr>
<tr>
<td>t-value</td>
<td>-.939</td>
<td>.284</td>
</tr>
</tbody>
</table>

*Note:* All values are mean ± standard deviation, *p<.05.

<Table 6> illustrates the trunk rotation results for the LBP Group and both sides for the lower extremity muscle flexibility. In the case of the trunk rotation, there were no significant differences demonstrated for both sides and the LBP Group and the interactions. However, in the both sides of the LBP, dominant turned out to be significantly (p<.05) lower than that of the non-dominant. Such an aspect is considered to be due to the differences in the number of people of the LBP Group.

### 4. Discussion

This study compared the lower extremity muscle flexibility according to the LBP Group and both sides (dominant and non-dominant) for the high school baseball players, and the results were derived accordingly. A discussion of each question is as follows.
4.1. Discussion of the lower extremity muscle flexibility related results according to the LBP Group and both sides

In the case of the Thomas test for the LBP Group and both sides for the lower extremity muscle flexibility, the both sides’ main effect turned out to be significant, and the non-dominant athletes with LBP tended to have lower Thomas test values than the dominant.

Such results of the Thomas test signify that the hip flexor flexibility was lower in the dominant side of baseball players with LBP than the non-dominant side. Hence, it implicates that there is a tension of the anterior thigh muscle due to the decrease in the flexibility on the dominant side. It is also considered that such tension has the potential to induce LBP. Examining the studies related thereto, and according to a study which surveyed the prevention and treatment of lumbar spine injuries among the major league professional baseball players, it is highly likely that LBP can be induced if the tension of the anterior femoral flexor is high, and to prevent such, diagnosis and treatment as well as the prevention of damages is significant[25].

In the case of the hip extension test of the lower extremity muscle flexibility of the LBP Group and both sides, both sides and the LBP Group turned out to be significant. The players with LBP had significantly lower hip extension values in terms of non-dominants than the dominants. Furthermore, LBP turned out to be significantly lower in terms of dominant than the non-LBP. Such results of hip extension signify that the flexibility of hip extension angle was lower in the dominant side of baseball players with LBP than the non-dominant side. Hence, the flexibility of the iliopsoas and rectus femoris muscles, which are the dominant anterior thigh muscles, fell, which implicates that such tension may induce LBP. Examining the studies related thereto, and in a study on the relationship between core stability and communication among the high school baseball players, the decreased core stability was reported to be a potential risk factor for the players’ LBP, and hence, the core stability evaluation ought to be performed[26].

In the case of the LBP Group and the HBD test of both sides for the lower extremity muscle flexibility, there were no significant differences demonstrated in terms of the main effects of both side and the LBP Group, nor for the interactive effect.

Such HBD results did not demonstrate a significant difference, yet demonstrated a tendency of high tension. The high tension of the quadriceps muscle in the anterior thigh suggests the possibility of LBP induction. Examining the papers related thereto, and as a result of a survey conducted with 272 players who experienced LBP across 6 seasons among the Major League baseball players, it was reported that they returned through a rehabilitation program for an average of 51 days, among which, most players had rehabilitation focused on the improvement of their core stability and flexibility[27].

In the case of the LBP Group and the SLR test of both sides for the lower extremity muscle flexibility, the main effect of the LBP Group turned out to be significant. In terms of the non-dominant, the level of SLR turned out to be significantly higher for the LBP than for the non-LBP.

Such results of SLR suggest that the hamstring’s flexibility is high on the non-dominant side of the players of LBP. Based on the results discussed in the previous studies, a clear conclusion has not yet been reached. Examining the studies related thereto, it was reported that the hamstring’s length had a potential risk factor for LBP among high school baseball players, and such results were a guideline for the development of a future preventive program [28].

In the case of trunk rotation of the LBP Group and both sides for the lower extremity muscle flexibility, there were no significant differences demonstrated between both sides and the LBP Group and the interaction. However, trunk rotation for both sides and the LBP turned out to be significantly lower for the dominant than for the non-dominant. Such an aspect is considered to be due to the differences in terms of each individual of the LBP Group.
Such results signficate that the flexibility of baseball players with LBP turned out to be low for the dominant side rotation. Such a phenomenon suggests the possibility of inducing LBP due to the imbalance of the circuit related muscles. Examining the studies related thereto, the rotation of baseball players while hitting balls is accompanied by a twisting phenomenon in the direction opposite to the direction of movements. Given such a reason, it is reported that the LBP of baseball players is caused  

5. Conclusion

Gathering the results above, and as a cause of LBP among the high school baseball players, there is a possibility that a decrease in flexibility due to hip flexion and extensor tension may be induced, and hence, the possibility of inducing LBP was verified due to the excessive use of the back muscles of the accelerator during the pitching and hitting sections. In the future studies, it is necessary to develop and apply the programs which can prevent and rehabilitate LBP.

6. References

6.1. Journal articles


7. Appendix

7.1. Authors contribution

<table>
<thead>
<tr>
<th>Initial name</th>
<th>Contribution</th>
</tr>
</thead>
</table>
| **Lead Author** DH | - Set of concepts ✔
| | - Design ✔
| | - Getting results ✔
| | - Analysis ✔
| **Corresponding Author* WC** | - Make a significant contribution to collection ✔
| | - Final approval of the paper ✔
| | - Corresponding ✔
| **Co-Author JT** | - Play a decisive role in modification ✔
| | - Significant contributions to concepts, designs, practices, analysis and interpretation of data ✔
| | - Participants in Drafting and Revising Papers ✔
| | - Someone who can explain all aspects of the paper ✔