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Physical function characteristics in Japanese high school volleyball players with low back pain

A case-controlled study

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Abstract

Low back pain (LBP) is a typical symptom in volleyball players, yet associated physical function factors have not been identified. This study purpose is to determine the relationship between LBP and physical function factors in order to identify potential factors for the management of LBP.

Participants were 123 male and female volleyball players of 15- to 17-year-olds who, completed a questionnaire regarding demographic details, presence of LBP, and years of volleyball experience. Participants were divided into 2 groups based on the presence of current LBP and evaluated on physical function tests. The results of the questionnaire response and physical function test were compared between the 2 groups. Data were analyzed using a multivariate logistic regression analysis with presence and absence of current LBP as the explanatory variable.

11.4% of all participants reported current LBP. Physical function factors associated with current LBP were a positive modified Thomas test, years of volleyball experience and reduced range of motion of shoulder horizontal abduction on the dominant hand side.

The associations between physical function factors and LBP found in this survey suggest that attention should be given to more experienced players with decreased flexibility of hip and shoulder flexors on the dominant side in order to manage LBP in high school volleyball players.

Abbreviations: BB = backbends in a supine position, ER = external rotation, FFD = finger-floor distance, FL = flexion, HAB = horizontal abduction, HBD = heel-buttock distance, LBP = low back pain, MTT = modified Thomas test, ROM = range of motion.

Keywords: low back pain, volleyball, injury prevention, high school students, physical function

1. Introduction

Low back pain (LBP) is a common condition in adolescent sports players.[1,2] Repetitive jumping, overhead hitting, and other movements in volleyball may expose the lumbar spine to greater stress than that which occurs in normal life. A survey of high school volleyball players in Japan reported that LBP in the previous year was experienced more commonly than pain in other body regions including the shoulder, elbow, knee and ankle.[3] In the field of sport, there are many occasions when athletes complain of pain even though they have not been injured.[4] However, ongoing pain leads to a deterioration in sports performance with difficulty maintaining a competitive game. Hence, pain management in sport is important.

Volleyball is a relatively safe sporting activity with comparatively few injuries,[5,6] since opposing teams are separated by the net.[7] Despite this, it has been shown that volleyball players have a high prevalence of LBP.[8–11] Kilic et al stresses the importance of focusing on other specific musculoskeletal injuries besides the more common knee and ankle injuries in volleyball players.[12] While musculoskeletal injuries are common among volleyball players, there are few effective preventive measures.[12] Patel et al indicated that the most common underlying cause of LBP in adolescent athletes is lumbar spondylolysis, although the cause of LBP may vary in different types of competitive sports.[13] For example, an MRI investigation of volleyball players and swimmers reported a significantly greater number of lumbar disc abnormalities in volleyball players.[14] Despite this evidence, a previous study revealed that 60% of high school volleyball players with LBP failed to consult with their coaches or doctors for help with LBP management.[3] Without medical consultation it is difficult to identify the underlying cause of LBP in high school volleyball players. In this case physical function tests that can be easily performed in the sporting arena may be useful for screening for potential risk factors in the development of LBP.

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Adolescent children have a higher participation rate in sports compared to older children and adults,[15] and volleyball players tend to have more injuries than athletes undertaking other sports.[16] Participation in sport is one of the leading causes of LBP in young people,[17] and the prevalence of LBP in people who play sport on a daily basis increases after the age of 17 years.[10] In addition, the prevalence of LBP in collegiate volleyball players is greater than high school volleyball players.[18] This may be due to the excessive training (hours per week) in school children and young athletes.[19,20]. Prevention of LBP in adolescent players who are still skeletally immature may mitigate the development of LBP in older players. For these reasons, the present study was designed to include high school players under the age of 17 years.

Despite many previous reports investigating the relationship between physical function factors and LBP, little is known about these association in high school volleyball players. Abdelraouf et al suggested that collegiate athletes with LBP had decreased trunk extensor muscle endurance.[21] Auvinen et al stated that volleyball is one of the youth sports where there is a correlation between a higher prevalence of LBP and shoulder pain, especially in boys.[22] It is known that overuse injuries in volleyball is common in the spine or shoulder.[23] These results suggest that dysfunction of the lumbar spine and shoulder joint may coexist, but this relationships in adolescence volleyball player is unclear. Another factor, hamstring or quadriceps femoris tightness has frequently been reported to be a risk factor for LBP.[24–26] Furthermore, poor sleep quality[27,28] and increased body weight or body mass index (BMI)[29,30] are also associated with chronic LBP.

The main focus of this study is to determine whether physical function factors considered to be associated with LBP play a role in the development of LBP in younger volleyball players. Therefore, our purpose was to evaluate a broad range of factors from questionnaire and physical function tests to identify which factors may be associated with a current complaint of LBP in volleyball players aged 15 to 17 years. We hypothesized that extremity function, rather than lumbar spine function, is associated with LBP in high school volleyball players. The results of this study may provide information towards designing rehabilitation and prevention programs for high school volleyball players.

2. Methods

2.1. Participants

This study was a case-controlled design. The inclusion criteria were high school male and female volleyball players aged 15 to 17 years who were training with a volleyball club team. We invited 32 elite high school volleyball teams in Saitama, Japan (population 7,335,000) to take part in this study, with detailed study information sent to each team. A total of 123 volleyball players (63 males, 60 females, 15.8 ± 0.7 years old) formed a sample of convenience recruited from 8 public high schools. The case group subjects consisted of high school players who were currently experiencing LBP, as the purpose of the study was to identify factors associated with LBP in high school volleyball players. Subjects in the control group were chosen from high school players without LBP. Controls were matched to the cases according to age, sports, and number of training hours per week. One control group per case group was chosen.

The study was carried out in accordance with the Declaration of Helsinki and was approved by the Ethics Committee at Faculty of Health and Medical Care, Saitama Medical University, Japan (M-73). The purpose of the study was explained by letter and verbal communication with the school principal and volleyball club coach in each high school, and the principal's written consent was obtained. A similar explanation was also provided to the participants and their parents, and again written consent were obtained.

2.2. Data collection

We collected data, including questionnaires and physical function tests, on the athletes in the high school gymnasium. The investigation period was from July to October, 2017. The survey items were demographic details, environmental factors, the presence of current LBP during volleyball, and physical function. Demographic details include gender, age (years), height (cm), body weight (kg), dominant hand, and years of experience as a volleyball player. In addition, we calculated the players BMI (kg/m^2). A binary variable for gender was set to 1 for female players and 0 for male players. Hand dominance was determined by the arm used to spike or serve. Environmental factors assessed were volleyball court position (spiker [strong side, weak side, or middle blocker], or others [setter or libero]), spike form (bow and allow, circular, or straight), average volleyball practice time, practice days per week, presence or absence of static stretching after playing, and average sleep time. Based on previous research,[8] current LBP during practice in volleyball was defined as pain or discomfort in the low-back, within the region between the lowest rib and the buttocks. Participants with symptoms associated with menstruation were not classified as LBP. Participants replied with "yes / no" to the question of lower extremity pins and needles or numbness, which was used to identify neurological symptoms. When answering the questionnaire, the players were located away from the team's coaches. Based on the questionnaire data, participants were divided into 2 groups; those with current LBP during volleyball and those without. A binary variable for the presence or absence of LBP was set to 1 for players in the case group and 0 for players in the control group.

Physical function tests included the Ito test (sec),[31,32] heel-buttock distance (HBD, cm), backbends in a supine position (BB, cm), finger-floor distance (FFD, cm), side FFD (cm), full-squat test, and modified Thomas test (MTT)[33,34] (Fig. 1). We also measured active shoulder flexion (FL), external rotation (ER) and horizontal abduction (HAB) range of motion (ROM, degree), as well as trunk rotation ROM using a plastic goniometer (GS-100; OG Wellness Inc., Japan) in 5-degree increments.

In an effort to address potential sources of bias, the case and control group subjects were taken from the same population of high school volleyball players. Additionally, in order to reduce measurement error as much as possible, all tests of physical function were measured by one skilled physical therapist with over 10 years of experience.

2.3. Physical function tests

The Ito-test measures trunk extensor endurance (Fig. 1A).[31] Participants were asked to lie in prone position lifting the sternum off the floor. A small pillow was placed under the lower abdomen to decrease the lumbar lordosis.[29] During this test, the participants were asked to maintain the test positions for as long as possible, with a maximum of 180-seconds. The HBD was

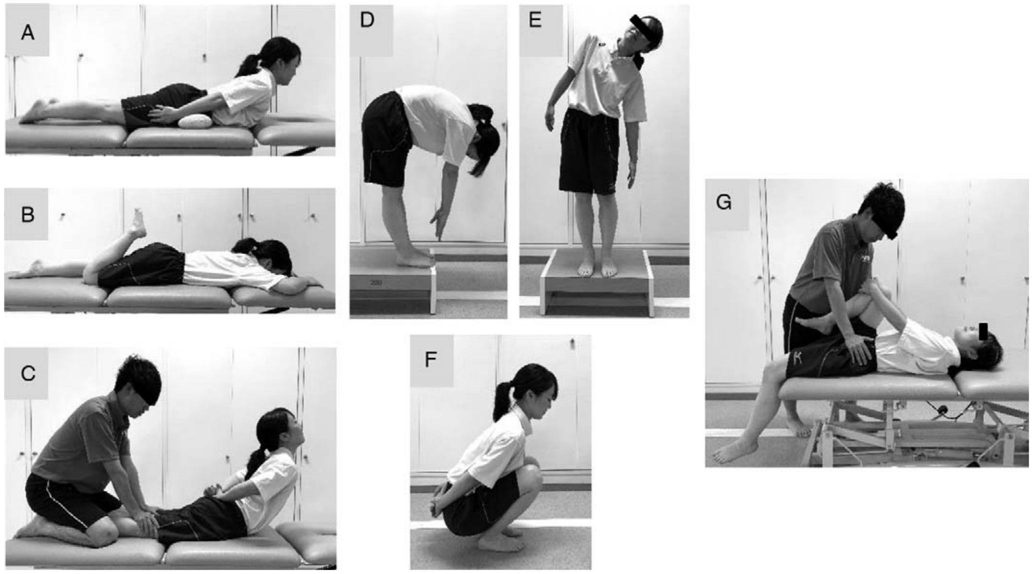

Figure 1. Physical function tests. A: Ito test, B: heel-buttock distance, C: backbends in a supine position, D: finger-floor distance, E: side finger-floor distance, F: full-squat test, G: modified Thomas test.

measured in the prone position (Fig. 1B). To evaluate the quadriceps muscle extensibility, the prone subject actively flexed their knees; the distance between the heels and the buttocks was measured when the pelvis started to lift off from the floor. The BB was used to evaluate spine extension flexibility (Fig. 1C). For the measurement of the BB, the subject's legs were held down in the prone position. The subject lifted their torso to the maximum and the distance between the chin and the floor measured. Subjects were not allowed to rotate their trunk during testing. For the measurement of the FFD, participants stood on a platform 20 cm high, flexed their trunk reaching with both arms to the floor (Fig. 1D). The distance from the tip of the third finger to the floor when the trunk and hip was at maximum FL was measured as the FFD. Subjects were not allowed to flex their knee during FL testing. When the subject was unable reach the surface of the box, positive values were noted. Negative values (marked with 'minus') were obtained when the participant was able reach below the top surface of the box. Likewise, for the measurement of the Side-FFD, participants stood on a platform 20 cm high, side flexed their trunk reaching with their arm to the floor (Fig. 1E). This distance from the tip of the third finger to the floor when the trunk was at maximum side flexion was measured as the side FFD. Subjects were not allowed to flex, extend or rotate their trunk during testing. We evaluated the ability to squat to assess for decreased ankle joint flexibility (Fig. 1F). For this test, participants were asked to squat while keeping both hands behind their back. Subjects were not allowed to lift their heels of the ground during this test. The test was positive if a participant fell backward. We used the MTT to evaluate iliopsoas flexibility (Fig. 1G). The participant lay in a supine position on the table with the pelvis close to the edge. The subject held the contralateral leg close to their chest, while the examined leg was allowed to relax. The examiner stabilized the participant's pelvis to keep the lumbar spine in neutral position. In accordance with previous studies of MTT[30,31] reliability, we did not allow any change in pelvic tilt and lumbar lordosis during testing. When the hip joint on the side tested was in flexion, flexibility was noted as positive. Conversely when the hip was in extension flexibility was notes a negative. A binary variable for MTT was set to 1 for players with positive flexibility and 0 for players with negative flexibility. Active shoulder and trunk ROM were measured bilaterally, and assessed by standard goniometric measurement. Shoulder FL was assessed while the participant was in a supine position. Shoulder ER ROM was assessed with the shoulder in 90° of abduction while the participant was in a supine position. Shoulder HAB was assessed with the shoulder in 90° of abduction and the elbow in 90° flexion while the participant was in a prone position without trunk rotation. Trunk rotation was assessed while the participant was in a sitting position.

2.4. Sample size

We calculated the sample size using power analysis application G*Power 3.1.9.2 (http://www.gpower.hhu.de/). In order to compare the questionnaire items and physical function items between the LBP and asymptomatic group, the effect size d was set to 0.5 ($\alpha = .05$, $1\text{-}\beta = 0.8$) for the independent t-test and the effect size w was set to 0.3 ($\alpha = .05$, $1 - \beta = 0.8$) for the chi-squared test. We estimated that the level of effect size was medium for both analyses. As a result, the number of participants required were 128 cases (64 per group) for the t-test and 88 for the $\chi 2$ test. Furthermore, the sample size of the logistic regression was determined according to Altman's formula ($n \geqq 10$*number of independent variables). Therefore, we tried to recruit at least 128 participants at the beginning of this study.

2.5. Statistical analysis

For statistical analysis we first performed simple tabulation for questionnaire items, and in the case of continuous variables means were calculated with standard deviations. Comparisons between groups were made using independent t-test for continuous variables and chi-squared test for categorical data. Following this, we used multivariate logistic regression analysis

Table 1

Comparison of questionnaire and physical function items between the LBP and asymptomatic group.

Variables	LBP (n=14)	Non-LBP (n=109)	*P*	Power (1−β)
Gender, n; M / F (%)	6 (42.9) / 8 (57.1)	57 (52.3) / 52 (47.7)	.51	0.32
Age (years)	16.1 (0.8)	15.8 (0.7)	.11	0.29
Experience as a volleyball player (years)	5.3 (2.6)	3.3 (1.8)	<.001	0.88
BMI (kg/m^2)	20.7 (1.7)	20.4 (1.6)	.55	0.10
Court position, n	Spiker: 9 (64.3) Others: 5 (35.7)	Spiker: 76 (69.7) Others: 33 (30.3)	.50	0.13
Spike form, n (Only spiker)	Bow and allow: 4 Circular: 3 Straight: 2	Bow and allow: 52 Circular: 8 Straight: 16	.11	0.99
Practice time/week on weekdays (hours)	3.0 (0.4)	3.0 (0.6)	.72	0.07
Practice time/week during holidays (hours)	4.0 (0.3)	3.8 (0.5)	.052	0.35
Stretching after practice, n (%)	Presence: 11 (78.6)	Presence: 80 (73.4)	>.99	0.16
Sleep time /week (hours)	6.3 (0.7)	6.4 (0.9)	.55	0.07
Ito test (sec)	163.8 (34.3)	165.9 (34.3)	.83	0.06
HBD (cm)				
dominant hand side	5.5 (3.5)	6.8 (4.3)	.27	0.21
non-dominant hand side	4.8 (2.9)	6.8 (4.4)	.09	0.47
BB (cm)	52.1 (11.1)	54.4 (8.2)	.36	0.13
FFD (cm)	-8.1 (11.9)	-5.8 (11.2)	.47	0.11
Side FFD (cm)				
dominant hand side	42.4 (7.8)	42.1 (6.3)	.84	0.05
non-dominant hand side	41.6 (7.5)	41.7 (6.0)	.94	0.05
full-squat test, n	Positive: 3 (21.4)	Positive: 28 (25.7)	.51	0.12
MTT, n	Positive: 7 (50.0)	Positive: 19 (17.4)	.01	0.99
Shoulder FL ROM (°)				
dominant hand side	176.4 (7.2)	178.4 (7.2)	.34	0.16
non-dominant hand side	177.5 (4.7)	179.1 (3.3)	.23	0.28
Shoulder ER ROM (°)				
dominant hand side	116.4 (13.2)	112.4 (13.5)	.30	0.18
non-dominant hand side	102.5 (10.3)	102.5 (10.3)	.99	0.05
Shoulder HAB ROM (°)				
dominant hand side	44.3 (13.3)	55.4 (15.7)	.01	0.76
non-dominant hand side	51.1 (15.0)	61.9 (15.7)	.02	0.69
Trunk rotation ROM (°)				
dominant hand side	66.4 (11.8)	66.3 (13.4)	.97	0.05
non-dominant hand side	71.8 (9.9)	66.9 (12.4)	.16	0.33

Continuous variables are represented as means with standard deviation; categorical variables are represented as numbers and percentages.
M=male, F=female, BMI=body mass index, HBD=heel-buttock distance, BB=backbends from a supine position, FFD=finger-floor distance, MTT=modified Thomas test, ROM=range of motion, FL=flexion, ER=external rotation, HAB=horizontal abduction.

with presence and absence of current LBP as an explanatory variable after determining independent variables that were significant in a univariate logistic regression analysis. We used forward selection by likelihood test ratio as variable selection for a multivariate logistic regression analysis. In this analysis, gender and BMI were entered as adjustment factors. Furthermore, to account for the effect of multicollinearity, we selected items that were considered to be more affected if there were items with correlation coefficients between the items selected in the univariate logistic regression analysis that were greater than 0.7. All statistical analyses were conducted using the IBM SPSS Statistics for Windows, Version 25.0 (Armonk, NY: IBM Corp Released 2017), and the level for significance was set at $P=.05$.

3. Results

We obtained informed consent from the parents of 123 participants. 123 high school volleyball players completed the questionnaire and physical function examination with a 100% response rate. There were no missing data for all items in this study. Based on the presence or absence of LBP, participants were divided into a LBP group (n=14) or asymptomatic group (n=109).

3.1. Comparison between groups for questionnaire and physical function items

Table 1 shows the comparison between groups for questionnaire and physical function items. Since the number of participants was lower than planned, a post-hoc power analysis was conducted. There were more than four items correlating with current LBP; experience as a volleyball player, the MTT, and shoulder HAB ROM on the dominant and non-dominant hand side. Factors "experience as a volleyball player" and "MTT" indicated that power would be greater than 0.8. Mean years of volleyball experience was greater in the LBP group compared to the asymptomatic group. In addition, the proportion of positive MTT was significantly greater in the LBP group compared to the asymptomatic group. Shoulder HAB ROM on dominant and non-dominant hand side was significantly reduced in the LBP

Table 2

Factors associated with current LBP in high school volleyball players (univariate logistic regression analysis).

					95%CI	
Variables (n=123)	**B**	**SE**	***P***	**Odds**	**Min**	**Max**
Gender	0.38	0.58	.51	1.46	0.48	4.49
Age	0.64	0.40	.12	1.89	0.86	4.17
Experience as a volleyball player	0.43	0.14	.002	1.54	1.17	2.02
BMI	0.11	0.18	.55	1.11	0.79	1.58
Court position (Spiker or others)	0.16	0.59	.79	1.18	0.37	3.77
Spike form (Only spiker)	0.32	0.40	.42	1.38	0.63	3.01
Practice time/week on weekdays	−0.01	0.06	.81	0.99	0.89	1.10
Practice time/week during holidays	0.12	0.08	.11	1.13	0.98	1.31
Stretching after practice	0.29	0.69	.68	1.33	0.35	5.10
Sleep time /week	−0.21	0.34	.55	0.81	0.42	1.59
Ito test	−0.002	0.01	.82	1.00	0.98	1.01
HBD						
dominant hand side	−0.08	0.07	.27	0.92	0.80	1.06
non-dominant hand side	−0.13	0.08	.95	0.87	0.75	1.02
BB	−0.03	0.03	.36	0.97	0.91	1.03
FFD	−0.02	0.03	.47	0.98	0.93	1.04
Side FFD						
dominant hand side	0.01	0.04	.84	1.01	0.93	1.10
non-dominant hand side	−0.003	0.05	.94	1.00	0.91	1.09
full-squat test (positive=1, negative=0)	−0.24	0.69	.73	0.79	0.21	3.03
MTT (positive=1, negative=0)	0.78	0.30	.009	2.18	1.22	3.89
Shoulder FL ROM						
dominant hand side	−0.56	0.04	.19	0.95	0.87	1.03
non-dominant hand side	−0.09	0.06	.14	0.92	0.82	1.03
Shoulder ER ROM						
dominant hand side	0.02	0.02	.30	1.02	0.98	1.07
non-dominant hand side	0.00	0.03	.99	1.00	0.95	1.05
Shoulder HAB ROM						
dominant hand side	−0.05	0.02	.02	0.95	0.91	0.99
non-dominant hand side	−0.47	0.02	.02	0.95	0.92	0.99
Trunk rotation ROM						
dominant hand side	0.001	0.02	.97	1.00	0.96	1.04
non-dominant hand side	0.04	0.03	.16	1.04	0.99	1.09

B=regression coefficient, SE=standard error, CI=confidence interval, BMI=body mass index, HBD=heel-buttock distance, BB=backbends from a supine position, FFD=finger-floor distance, MTT=modified Thomas test, ROM=range of motion, FL=flexion, ER=external rotation, HAB=horizontal abduction.

group compared to the asymptomatic group. There was no significant difference between the groups for all the remaining items.

3.2. Factors associated with current LBP

Results of the univariate logistic regression analyses are shown in Table 2. Univariate logistic regression analysis with current LBP, questionnaire items and physical function items included indicated a significant association among LBP and the years of experience as a volleyball player, MTT, and shoulder HAB ROM on the dominant or non-dominant hand side.

Results of the multivariate logistic regression analyses are shown in Table 3. In this analysis, significant items from the univariate logistic regression analysis were entered with adjustment factors of sex and BMI. Based on the results of this analysis, factors related to current LBP were MTT ($P=.001$), years of experience as a volleyball player ($P=.002$) together with shoulder HAB ROM on the dominant hand side ($P=.045$). The odds ratio of each items were 2.33 (95%CI: 1.20 to 4.54) for

Table 3

Factors associated with current LBP in high school volleyball players (multivariate logistic regression analysis).

					95%CI	
Variables (n=123)	**B**	**SE**	***P***	**Odds**	**Min**	**Max**
MTT	0.85	0.34	.001	2.33	1.20	4.54
Experience as a volleyball player	0.48	0.17	.002	1.61	1.15	2.25
Shoulder HAB (dominant hand side)	−0.05	0.02	.045	0.95	0.91	0.99
Constant	−2.19	1.37	.11	0.11		

Likelihood ratio test, $P<.001$; Hosmer-Lemeshow test, $P=.94$; percentage of correct classifications was 91.1%.

B=regression coefficient, SE=standard error, CI=confidence interval, MTT=modified Thomas test (positive=1, negative=0), HAB=horizontal abduction.

the MTT, 1.61 (95%CI: 1.15 to 2.25) for the years of experience as a volleyball player, and 0.95 (95%CI: 0.91 to 0.99) for shoulder HAB ROM on the dominant hand side. The results of the Hosmer-Lemeshow test in this model were shown to be compatible with $P=0.94$, with the percentage of correct classifications being 91.1%.

4. Discussion

The purpose of this study was to determine the physical functional factors that are associated with a current episode of LBP in high school volleyball players. According to a previous study, diagnostic imaging in adolescent athletes with LBP showed that 50% of the sample had signs of lumbar spondylolysis, which may explain the ongoing nature of LBP in volleyball players.[35] Overuse injury has been widely shown to cause playing time loss for professional volleyball players and also to a lesser extent for middle and high school players.[23,36–40] On the other hand, the management of LBP is important, since it was reported that the percentage of players with time lost to sport due to injury of the lumbar spine in collegiate volleyball players is 12.9% for males and 8.5% for females.[41] Thus, it would seem plausible to suggest that managing LBP in high school volleyball players might reduce time lost to sport in the future.

In the present study, logistic regression analysis was used to identify factors associated with current LBP from the questionnaire and physical examination items. A significant relationship was found between decreased hip flexor extensibility identified by MTT, years of experience as a volleyball player, as well as reduced shoulder HAB ROM on the dominant hand side and presence of current LBP.

A positive MTT indicates that the hip flexor muscles are shorter than normal; which may be associated with excessive lumbar lordosis or anterior pelvic tilt. Previous studies have reported that shortening of the iliopsoas and increased lumbar lordosis were associated with LBP in adolescent athletes.[42] In volleyball, it is often required to extend the lumbar spine, such as during spike, serve, or dive. It is possible that subjects with short hip flexors repeatedly overstress their lumbar spine in extension during training and games. Therefore, it is important to regularly check for shortening of the hip flexor muscles with MTT and to improve flexibility if the MTT is shown to be positive.

A reduced range of shoulder HAB ROM on the dominant hand side was also associated with current LBP. As a characteristic of shoulder ROM in volleyball players, there is a decrease in internal rotation ROM and consequent increase in ER ROM,[43] however, there are few reports of a decrease in HAB in volleyball players. Narita et al showed that divers compensate with increased extension of the lumbar spine due to a decline in their shoulder elevation ROM.[44] Although shoulder HAB ROM is required at the back swing of spike or serve motion, it is possible that a compensation movement due to excessive rotation of the lumbar spine may occur with a decrease in shoulder HAB ROM. Therefore, it is important to periodically measure shoulder HAB ROM. We also need to consider interventions such as stretching of the pectoral muscles as well as anterior head of the deltoid, or coracobrachialis, which are thought to be related to a decrease in shoulder HAB ROM.

We found that years of experience as a volleyball player correlated with a current report of LBP. Sports specialization among young athletes is becoming more prevalent in a way to achieve future performance status. In particular, it is reported that volleyball requires longer practice sessions than other competitive team sports.[9] It is conceivable that repeated game-specific movements during volleyball practice and games over prolonged time periods may increase musculoskeletal injury with overuse. Aagaard et al reported that elite senior volleyball players have many chronic injuries due to overuse with practice repetition.[45] In addition, Post et al reported that exceeding 8 months per year in a single sport was associated with overuse injury in volleyball.[46] Although spondylolysis is the most common condition in adolescent athletes, the majority of LBP in mature athletes has been suggested to be mechanical. A longer time commitment to competition-specific training may be a factor in the development of LBP. In other words, it is likely that high school players who have been playing volleyball for many years are more likely to develop LBP from overuse. Therefore, it is important to educate young players to prevent the development of LBP.

Our study has several limitations. First, we relied on the honesty of the participants to report the presence of LBP, hence accuracy of this data cannot be determined. Second, in players with a history of current LBP it was not possible to diagnose the type of tissue disorder. Future research may seek a more detailed evaluation of the injured players to determine this. However, the physical function tests used in this study may prevent the development of LBP because it can be self-checked in daily life. Third, a positive MTT or a reduction in shoulder HAB ROM on the dominant hand side is related to a current episode of LBP, however, the exact nature of these limiting factors is not clear. Fourth, the sample was obtained from high school volleyball players in Saitama, Japan. Since volleyball practice sessions may differ in other countries, it may not be possible to extrapolate these data to all high school volleyball players.

In conclusion, our results provide some indication that volleyball players who start volleyball at younger age need educational guidance on the development of LBP, particularly if the player has a decreased hip flexor extensibility or a reduction in shoulder HAB ROM. Such players may require specific rehabilitation. Taking these matters into account, more attention should be paid when managing volleyball players to the individuals years of experience as well as any decrease in hip flexor muscle extensibility, and a reduction in shoulder HAB ROM. These findings may contribute to the development of further studies on the prevention and management of LBP in younger athletes.

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