TITLE:

Unilateral horizontal and lateral jump performances are associated with the competitive level of collegiate soccer players

ABSTRACT

This study examined hypothesis that unilateral horizontal (forward) and lateral jumps can be a convenient test for discriminating the competitive level of collegiate male soccer players. Thirty-one players were recruited from a collegiate soccer team and were allocated to regulars (n = 15) or non-regulars (16) on the basis of their participation in matches, whose morphological and body composition variables were similar in the two groups. The performances of unilateral jumps for vertical, horizontal, lateral-inside and lateral-outside directions were determined. In addition, power output in unilateral leg extension was also measured using an isovelocity dynamometer at a preset velocity of 0.8 m/s. In the two groups, leg extension power and jump performances had no significant lateral dominance. There were no significant differences between the regulars and non-regulars in the leg extension power and vertical jump height. However, the distances of horizontal and lateral jumps were significantly greater in the regulars than in the non-regulars. For the non-regulars, the leg extension power was significantly associated with the scores of the vertical (r = 0.596, $p < 0.05$) and horizontal (r = 0.623, $p < 0.05$) jumps. For the regulars, however, only the association between the vertical jump height and leg extension power was significant (r = 0.594, $p < 0.05$). Thus, the current results supported hypothesis and

highlight an importance of training for improving the power generation capability of the lower body to horizontal and lateral directions rather than vertical direction in collegiate soccer players.

K**EY WRODS**:

field test, dominant and non-dominant legs, leg extension power, lateral dominance

INTRODUCTION

During a soccer match, the power generation capability of the lower body plays an important role in executing different activities such as sudden stopping as well as changing running speed and direction (9). For soccer players and their coaches, therefore, it is essential to establish a test that reliably enables assessment of the power generation capability of the lower body in relation to competitive levels.

Many studies have used the vertical jump test to evaluate the lower body power in soccer players. For senior male soccer players, however, previous findings on whether the vertical jump test can discriminate the competitive level of players are inconclusive. Some studies denied this (3, 9, 17, 20), but others observed a significant association between jump height and team success (1) or a difference in jump height between elite and amateur players (5, 18). Thus, the idea that vertical jump can conveniently discriminate players with different levels of match performance is questionable (17).

Vertical jump assessment adopted in the previous studies cited above has been executed in a bilateral fashion. To our knowledge, no studies have ever tried to examine how unilateral jump performances can be associated with the competitive level of soccer players. In many different sports, most propulsive forces developed in various competitive situations are generated in a unilateral mode (13). Therefore, unilateral jump assessments in horizontal and/or lateral directions as well as the vertical direction would appear to have an advantage to obtain a true appreciation of functional muscular lower-limb capabilities in relation to the profiles of competitive activities (13). This is also true for soccer players because the representative actions involved in soccer games, such as short sprinting, changes of direction, side-to-side cutting, pivoting or sudden starts and stops, are characterized by horizontal or lateral force production in a unilateral fashion. Considering this, if one intends to examine how jump performance in soccer players can be associated with their competitive levels, the jump test should be executed in a unilateral fashion with horizontal or lateral force production.

The present study aimed to clarify whether unilateral jump could be a convenient test for discriminating the competitive level of collegiate male soccer players. We hypothesized that unilateral jump performances in horizontal and lateral directions are greater in the regulars than in the non-regulars, in spite of the lack of a significant difference in leg extension power and vertical jump height.

METHODS

Experimental approach to the problem

The present study aims to clarify the hypothesis that unilateral horizontal (forward) and lateral jumps can be a convenient test for discriminating the competitive level of collegiate male soccer players. To this end, we recruited participants from a collegiate soccer club and allocated them to regulars and non-regulars on the basis of their participation in the intercollege championship. The performances of unilateral jumps for vertical, horizontal (forward) and lateral (inside and outside) directions were determined for both dominant and non-dominant leg. In addition, the power output in unilateral leg extension was also determined by the use of an isovelocity dynamometer to examine how the performances of the jump tests can be associated to leg extension power determined under laboratory setting. Two-way analysis of variance (ANOVA) was used to examine the effects of group (regulars and non-regulars) and direction (vertical, horizontal, lateral-inside and lateral-outside) and their interactions on the performances of unilateral jumps.

Subjects

Thirty one male collegiate soccer players (age, 20.2 ± 1.1 yrs; body height, 174.1 ± 5.4 cm; body mass, 68.8 ± 5.5 kg; mean ± SD) voluntarily participated in the present study. All subjects were outfield players and had experience of competitive soccer training for 12.8 (± 1.7) yrs (10 to 16 yrs). All players were recruited from a collegiate soccer club that was ranked third in the Japan Intercollege Association Football Championship Tournament in 2012 and 2013. Leg dominance was defined by players' reports with regard to the leg preferentially used for kicking and confirmed by an experimenter observing the subjects play during official games. Five of the players were left-footed and the others were right-footed. For one year prior to the measurements, each player had nearly the same weekly schedule, which comprised about 3 hours of training per day, 5 days per week, and 1 game on the weekend. On the basis of their participation in the intercollege championship, the players were allocated to two groups: 15 regulars and 16 non-regulars. The physical characteristics of the players are summarized in Table 1. There were no significant differences between the regulars and non-regulars in height, body mass and body composition variables determined using a bioelectrical impedance apparatus with a leg-to-leg system (DC-320, Tanita, Japan). This study was approved by the Ethics Committee of the National Institute of Fitness and Sports in Kanoya. Prior to any measurements, the subjects visited the laboratory and were fully informed about the procedures and possible risks involved as well as the purpose of the study. Written informed consent was obtained from all participants.

(Table 1 about here)

Procedures

The present study determined the performances of unilateral jumps and leg extension power in an indoor sports hall. In the measurements, the participants wore their own indoor training shoes. The jump and power tests were performed on the same day. First, the measurements of unilateral leg extension power were executed. After the completion of the power test, the participants performed the unilateral jump tests. Prior to the test measurements, the participants were asked to perform a standardized warm-up, which involved stretching, jogging at a self-selected pace, and short sprints at approximately 70–80% of each individual’s maximal effort. All measurements were performed with an interval of more than 24 hours after the completion of a training session.

Measures.

Measurements of unilateral leg extension power.

An isovelocity dynamometer (Kick Force, Takei Scientific Instruments, Japan) was used to determine unilateral leg extension power (Figure 1). This apparatus includes force and position sensors and enables the determination of power during knee-hip extension movements under a preset linear velocity. The linear velocity at which the foot pedal is allowed to move is held at the preset velocity by a mechanism consisting of a DC motor and a driving screw, which is connected to the pedestal of the foot pedal. The foot pedal, to which the force sensor is attached, moves away horizontally on the guide rail. In the measurements, the linear velocity of the foot pedal was set at 0.8 m/s. The force developed to the foot pedal and the data obtained through a position sensor were sampled at 2 ms and introduced to a recorder with a built-in computer. Power was calculated as the product of the detected force and linear velocity every 2 ms and averaged by the number of sampling data. The average power was displayed in the recorder in W. In the measurements, the subjects sat on a seat with their arms folded over their chest and stabilized firmly at the hip, with their foot set on the foot pedal of the dynamometer. They were instructed to extend fully their leg as fast as possible. The non-exercised leg was placed on a stand set just beside the dynamometer in a relaxed and extended position. For each subject, the starting position of the foot pedal was adjusted so that the knee joint was flexed at 90 degrees.

(Figure 1 about here)

Before the maximal testing, the subjects were asked to perform unilateral leg extensions at the test velocity with submaximal efforts to familiarize themselves with the testing procedure. Following a 3-min rest after the end of the practice session, the subjects were requested to perform maximal voluntary unilateral leg extension five times with an interval of 30 seconds between the trials. The testing order for each of the dominant and non-dominant legs was randomized. A 3-min rest was taken between the trials of the two legs. For each of the dominant and non-dominant legs, the greatest power among the five trials was adopted as the unilateral leg extension power. The ratio of the power to body mass was calculated and used as the representative value for unilateral leg extension power.

Measurements of unilateral jump performances.

The present study determined the performances of unilateral jumps in vertical, horizontal and lateral-inside and -outside directions. After the completion of the unilateral leg extension power measurements, the participants were asked to perform the unilateral jumps in each of the four directions with submaximal effort to familiarize themselves with the test procedures. Following a 5-min rest after the end of the familiarization practice, two test trials were performed in a randomized order for each direction and leg. If the difference between the two trials was more than 5%, the jump was performed again. For each jump score, the highest of the two or three measurements was adopted for analysis.

In the measurements, the participants were asked to jump using a single leg with their arms akimbo and land using the same leg. Each of the jump tasks was performed with a similar action mode as described by Meylan et al. (12). In the vertical jump task, the participant was instructed to sink to a self-selected depth as quickly as possible from the upright position with the foot of the designated testing leg on the contact mat system (Multi Jump Tester, PH-1260D, DKH, Japan) (14) and then jump as high as possible. The jump height was calculated from the flight time determined using the contact mat system (14). In the horizontal and lateral jump tasks, the participant stood with the foot of the designated testing leg, with hands on hips, on the floor where two straight lines crossing at right angles had been drawn. In the horizontal task, the participant was instructed to stand with adjustment of the toe of the jumped leg to the inside of the transversal line and to sink to a self-selected depth as quickly as possible and then jump as far forward as possible. The distance of the perpendicular line from the heel at the landing to the inside of the transversal line at starting was measured to the nearest 1 cm with a tape measure and referred to as the horizontal jump score. Lateral jump was performed in each of the two directions of inside and outside. In each of lateral-inside and –outside jump tasks, the participant was instructed to stand with adjustment for the inside and outside, respectively, of the foot of the jumping leg to the inside of the longitudinal line, to sink to a self-selected depth as quickly as possible and then jump laterally in the designated direction as far as possible. The distances of the perpendicular lines from the outside and inside of the foot at the landing to the inside of the longitudinal line at starting were measured to the nearest 1 cm with a tape measure and referred to as the lateral-inside and -outside jump scores, respectively.

Repeatability of the leg extension power and jump performances.

In a preliminary study using 11 physical education collegiate students, we examined the repeatability of the unilateral leg extension power and jump performance measurements. The subjects performed each of leg extension power and jump measurements twice with an interval of 7 days. A paired Student's t-test showed that there were no significant differences between the two measurements in each of the leg extension power and jump performances for all directions. The intraclass correlation coefficients and coefficients of variation (%CVs) for the leg extension power and jump performance measurements were 0.80 to 0.97 and less than 3.0%, respectively.

Statistical analyses

Descriptive data are presented as means and SDs. In both regulars and non-regulars, there was no significant difference between the dominant and non-dominant legs in each of unilateral leg power and jump scores. For each of these variables, therefore, the mean value of the two legs was calculated as the representative value and used for comparison between the two groups. Two-way ANOVA was used to examine the effects of group (regulars and non-regulars) and direction (vertical, horizontal, lateral-inside and lateral-outside) and their interactions on the performances of unilateral jumps. When a significant interaction of group and direction was found, Student's unpaired t-test was used to test between the mean values of the two groups in each of the four directions. Student's unpaired t-test was also used to test the difference between the two groups in the single measures. In addition, effect size (Cohen's *d*) was calculated to express the magnitude of the difference between the two means of the measured variables. A simple linear correlation regression analysis was used to calculate the coefficients of correlations among the measured variables. Statistical significance was set at $p \leq 0.05$.

RESULTS

Unilateral leg extension power had no significant difference between the regulars (11.0 ± 1.0 W/kg) and non-regulars (10.5 ± 0.9 W/kg). Figure 2 shows the descriptive data on the performances of unilateral jumps. Two-way ANOVA showed a significant interaction of group and direction ($F = 32.237$, $p < 0.0001$). In the height of the vertical jump, there was no significant difference between the regulars and non-regulars. In the other directions, the regulars showed significantly greater jump scores than the non-regulars ($p < 0.0001$) with large effect size (d = 1.387–2.034). This result was the same even when the jump scores were expressed as the values relative to body height.

(Figure 2 about here)

For the regulars, only the vertical jump height was significantly associated with the leg extension power (r = 0.594, $p < 0.05$) (Figure 3). For the non-regulars, the leg extension power was significantly associated with the scores of the vertical (r = 0.596, $p < 0.05$) and horizontal (r = 0.623, $p < 0.05$) jumps. The regulars did not show significant associations between the scores of the vertical jump and other directional jumps. For the non-regulars, however, the vertical jump height was significantly associated with the distances of horizontal (r = 0.691, $p < 0.05$) and lateral-inside (r = 0.589, $p < 0.05$) (Figure 4).

(Figure 3 and Figure 4 about here)

DISCUSSION

The main result obtained here was that the regulars showed higher scores in horizontal and lateral jumps than the non-regulars, but the corresponding difference was not found in vertical jump. In addition, there was no significant difference between the two groups in leg extension power. These results support our hypothesis and indicate that, at least for collegiate male soccer players, unilateral jump performances in horizontal and lateral directions rather than vertical direction can be convenient measures for discriminating the competitive levels of the players under field conditions. The better performances of unilateral horizontal and lateral jumps for the regulars imply their greater ability to produce power in these directions than in the non-regulars. The motion of players in soccer matches is characterized by intermittent activity with sudden variation in direction, so the ability to change direction is considered as a logically valid criterion for fitness detection in soccer players (4). In this sense, the better performances of unilateral horizontal and lateral jumps for the regulars than in the non-regulars should be an advantage for performing changes of direction quickly during competitive matches, and consequently it would be a factor for discriminating them as the regulars.

The current study cannot provide evidence relating to the physiological background for the observed differences between the regulars and non-regulars in the unilateral jump performances. Both the regulars and non-regulars were members of the same team and had performed almost the same training regimens, including various straight and change-of-direction sprints, jumping and agility drills. Thus, the training status of the lower body can be considered to have been similar between the two groups. This is supported by the fact that, in addition to the morphological and body composition variables (Table 1), there were also no significant differences in unilateral leg extension power as well as vertical jump height. At the same time, these results suggest that the physical resources for power generation by the lower body may be almost the same between the two groups.

An interesting result obtained here is that, for the regulars, significant associations were not found between the scores of the vertical jump and each of the horizontal and lateral jumps. However, the vertical jump height for the non-regulars was significantly correlated with the performances of the horizontal and lateral-inside jumps. In addition, the observed associations between leg extension power and jump performances differed between the regulars and non-regulars. Namely, although the vertical jump height for the regulars was correlated with the leg extension power, the horizontal and lateral jump performances for them were not. However, the non-regulars showed significant associations between the leg extension power and not only vertical but also horizontal jump scores. These results indicate that, at least for the performances of the horizontal and lateral-inside jumps, the determinant factors differ between the regulars and non-regulars. As a result of biomechanical analysis for side steps (lateral-inside jumps adopted here) at different distances, Inaba et al. (8) have reported that, while extension torques and work done at hip, knee, and ankle joints contribute substantially to the changes in side step distances, hip abduction torque and work mainly act to accelerate the center of body mass laterally in the earlier phase of the movement and keep the trunk upright. Taking this into account, it seems that the observed differences between the two groups in the performances of horizontal and lateral jumps would be due to those in the function of the muscles around the hip joint, which can be associated with the acceleration of the body and/or maintenance of body balance during the execution of the tasks.

As well as leg extension power, the jump performances in all directions had no significant effect of leg for both regulars and non-regulars. For other team-sport players or physicaly active individuals, however, it is known that there is a significant difference between dominant and non-dominant legs in unilateral jump performances (6, 7, 13, 15, 19), although a few studies have failed to find this (10, 11). Soccer requires a unipedal posture to perform different technical movements such as shooting and passing (16). Thus, it seems that soccer players would also show a significant difference in the unilateral jump performances in relation to their lateral dominance. In addition to the unilateral leg extension power, however, the current result suggests that soccer players do not have lateral dominance in unilateral jump performances, being independent of the direction of jumping and competitive level. For soccer players, running, which is one of the typical bipedal movements, is a key movement during competitive activities. Bloomfield et al. (2) have shown that the frequencies of turning to the right and left during a soccer match performed by strikers, midfielders and defenders were similar between the two directions. Therefore, there is a possibility that the profiles of competitive and training activities in soccer, which are related to running and turning, might have led to bilateral symmetry in the unilateral jump performances, for both regulars and non-regulars.

PRACTICAL APPLICATION

The current study indicated that the regulars showed higher performances than the non-regulars in unilateral horizontal and lateral jump tasks, but the corresponding differences were not found in unilateral leg extension power and vertical jump height. These results suggest that the assessment of unilateral horizontal and lateral jumps could be a convenient tool for discriminating the competitive ability of collegiate male soccer players under filed conditions. At the same time, the findings obtained here indicate that for collegiate soccer players, the implementation of lunge and plyometric unilateral jump exercises for horizontal and lateral directions rather than vertical direction may be useful for improving their competitive levels.

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Figure legends

Figure 1

Measurements of unilateral leg extension power

Figure 2

Comparison between the regulars and non-regulars on the scores of the unilateral jumps. Values are the means of the dominant and non-dominant legs.

Figure 3

Relationships between leg extension power and each of vertical (upper panel) and horizontal (lower panel) jump scores. Values are the means of the dominant and non-dominant legs.

Figure 4

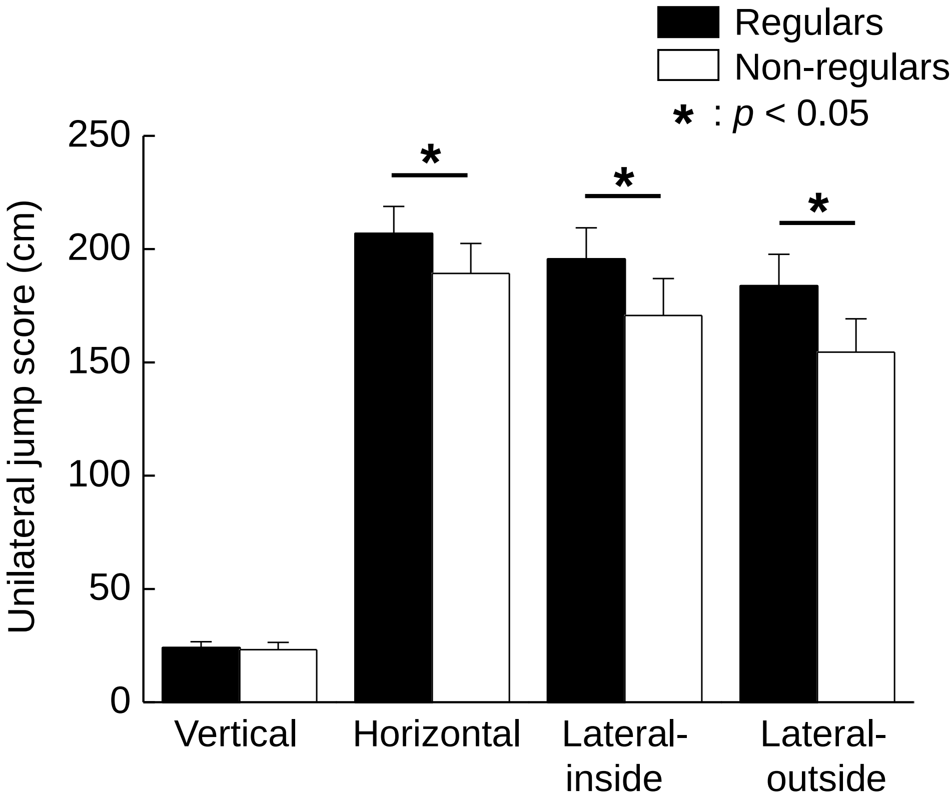
Relationships between the scores of vertical and each of horizontal (upper panel) and lateral-inside (lower panel) jumps. Values are the means of the dominant and non-dominant legs.

Table 1 Physical characteristics of subjects

Variables	Regulars, n = 15	Non-regulars, n = 16
Age, yr	20.5 ± 1.2	20.0 ± 1.0
Height, cm	174.4 ± 6.4	173.8 ± 4.5
Body mass, kg	69.7 ± 5.8	67.9 ± 5.3
% fat mass, %	10.9 ± 2.6	10.5 ± 2.2
Fat-free mass, kg	62.0 ± 4.8	60.7 ± 4.0

Values are means ± SDs.

Figure 1



Regulars
Non-regulars
* : p < 0.05
250
200
150
100
50
0
Unilateral jump score (cm)
*
*
*
Vertical
Horizontal
Lateral-inside
Lateral-outside

Figure 2

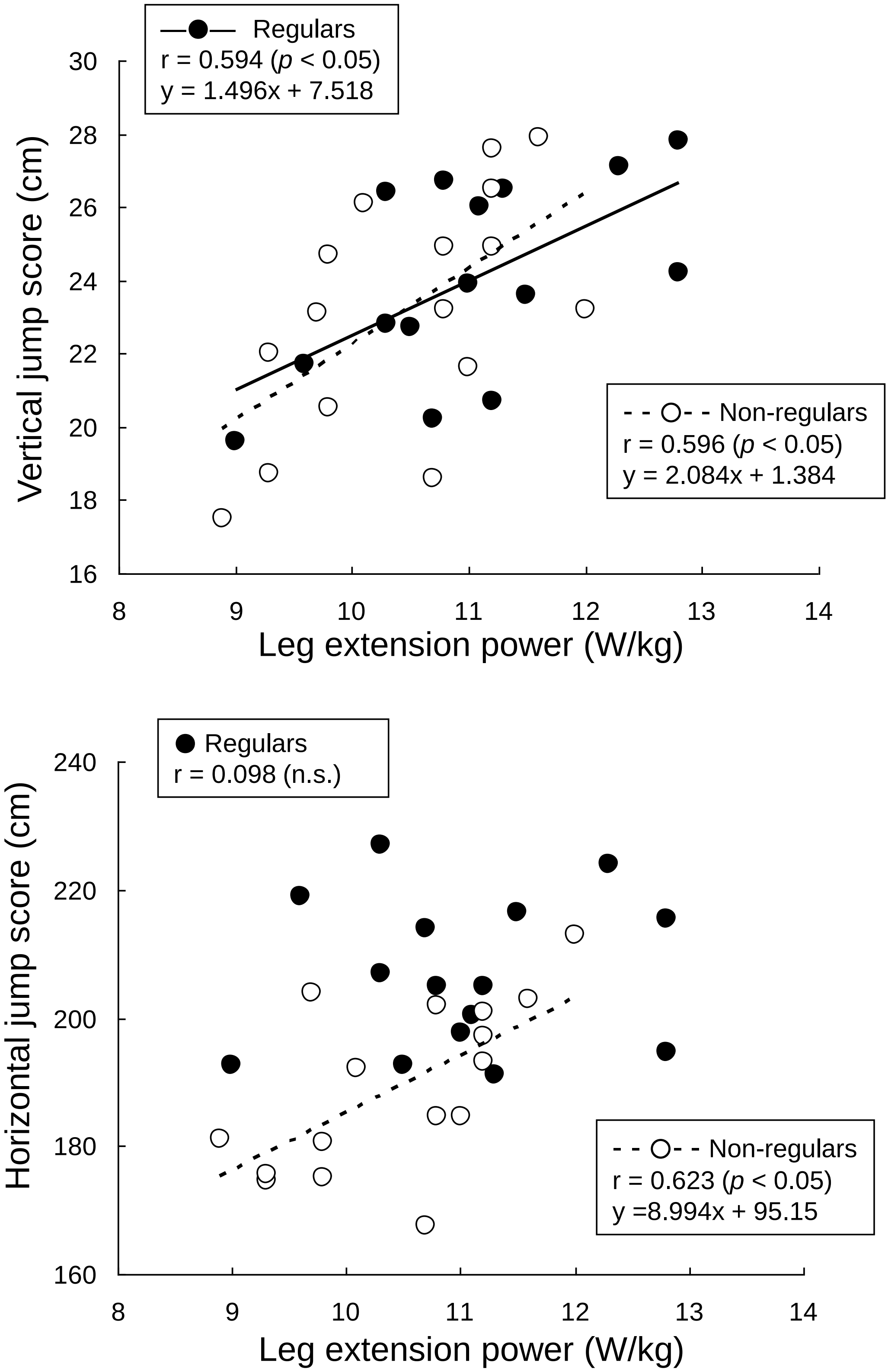

Regulars
r = 0.594 (p < 0.05)
y = 1.496x + 7.518
Non-regulars
r = 0.596 (p < 0.05)
y = 2.084x + 1.384
Vertical jump score (cm)
30
28
26
24
22
20
18
16
8
9
10
11
12
13
14
Leg extension power (W/kg)
Regulars
r = 0.098 (n.s.)
Non-regulars
r = 0.623 (p < 0.05)
y =8.994x + 95.15
Horizontal jump score (cm)
240
220
200
180
160
8
9
10
11
12
13
14
Leg extension power (W/kg)

Figure 3

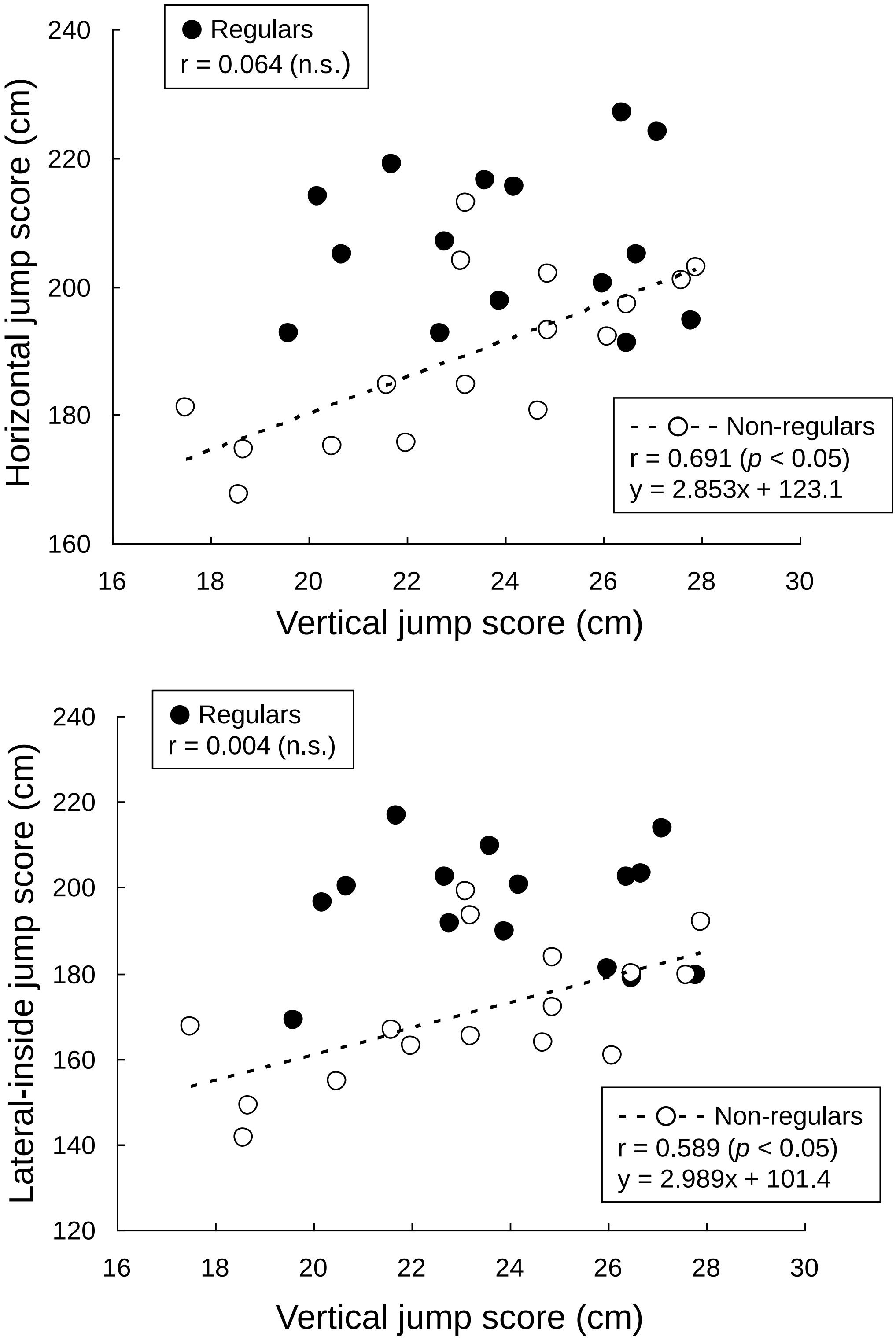

● Regulars
r = 0.064 (n.s.)
- - ○- - Non-regulars
r = 0.691 (p < 0.05)
y = 2.853x + 123.1
Horizontal jump score (cm)
Vertical jump score (cm)
240
220
200
180
160
16
18
20
22
24
26
28
30
● Regulars
r = 0.004 (n.s.)
- - ○- - Non-regulars
r = 0.589 (p < 0.05)
y = 2.989x + 101.4
Lateral-inside jump score (cm)
Vertical jump score (cm)
240
220
200
180
160
140
120
16
18
20
22
24
26
28
30

Figure 4