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4	Subsequent jumping increases the knee and hip abduction moment, trunk lateral tilt
5	and trunk rotation motion during single-leg landing in female individuals
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- **Running Title:** The effects of subsequent jumping

30 Abstract

Single-leg landings with or without subsequent jumping are frequently used to evaluate landing 31biomechanics. The purpose of this study was to investigate the effects of subsequent jumping 32on the external knee abduction moment and trunk and hip biomechanics during single-leg 33landing. Thirty young-adult female participants performed a single-leg drop vertical jumping 34(SDVJ; landing with subsequent jumping) and single-leg drop landing (SDL; landing without 35subsequent jumping). Trunk, hip and knee biomechanics were evaluated using a three-36 dimensional motion analysis system. The peak knee abduction moment was significantly larger 37during SDVJ than during SDL (SDVJ $0.08 \pm 0.10 \text{ Nm} \cdot \text{kg}^{-1} \cdot \text{m}^{-1}$, SDL $0.05 \pm 0.10 \text{ Nm} \cdot \text{kg}^{-1} \cdot \text{m}^{-1}$ 38¹, p = .002). The trunk lateral tilt and rotation angles toward the support-leg side and external 39hip abduction moment were significantly larger during SDVJ than during SDL (p < .05). The 4041difference in the peak hip abduction moment between SDVJ and SDL predicted the difference in the peak knee abduction moment (p = .003, $R^2 = .252$). Landing tasks with subsequent 42jumping would have advantages for evaluating trunk and hip control as well as knee abduction 43moment. In particular, evaluating hip abduction moment may be important because of its 44association with the knee abduction moment. 45

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47 Keywords: anterior cruciate ligament, risk factor, injury prevention, core, unilateral landing
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- 49 **Word count:** 3849 words (two figures and two tables)
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Introduction

An anterior cruciate ligament (ACL) injury is a serious athletic injury that requires surgical 52reconstruction and extensive rehabilitation^{1,2}. The majority of ACL injuries occur in noncontact 53situations, such as jump-landing or cutting maneuvers^{3,4}. Cadaveric landing simulation studies 54have shown that the knee abduction moment contributes to ACL injuries⁵⁻⁷. A large knee 55abduction moment during landing is found to be a predictor of ACL injuries in female athletes⁸. 5657Therefore, the knee abduction moment during landing has been considered a biomechanical risk factor for ACL injuries and should be reduced to prevent ACL injuries. Furthermore, female 58athletes demonstrate a larger knee abduction moment during landing than male athletes⁹ and 59are more likely to have ACL injuries than male athletes¹⁰. Therefore, the knee abduction 60 moment during landing tasks should be evaluated and reduced to minimize the risk of ACL 6162injuries, especially in female athletes.

63 Double-/single-leg drop landing and drop vertical jumping are common landing tasks used to evaluate the knee abduction moment^{8,11–14}. The presence or absence of a subsequent 64jump after landing leads to differences between the two landing tasks. A subsequent jump after 65landing is common in jump-landing sports, such as basketball, and has been shown to increase 66 the knee abduction moment during double-leg landing^{14,15}. On the other hand, another study 67reported no difference in the knee abduction moment between double-leg drop vertical jumping 68 and double-leg drop landing¹⁶. The aforementioned studies investigated double-leg landings^{14–} 69 ¹⁶; however, ACL injuries frequently occur during single-leg landing^{4,17}. Only one study by 70Hovey et al.¹³ reported that the subsequent jump did not increase the knee abduction moment 7172during single-leg landing in 11 female and 14 male athletes. However, because the effects of a subsequent jump on knee biomechanics differ between males and females during double-leg 73landing¹⁴, such effects during single-leg landing tasks should be investigated separately for 74male and female participants, especially as females have a greater risk of ACL injury. Hovey's 75

study included 11 female athletes, and this sample size did not allow a medium effect size (less than dz of 0.94) with a power of 0.80 and an alpha of 0.05. Further studies are needed to clarify the effect of subsequent jumping in females.

Trunk and hip biomechanics in the frontal and transverse planes have been considered to 79influence the knee abduction moment. Trunk lateral tilt and rotation toward the support-leg side 80 are associated with the knee abduction moment during athletic movements^{11,18–25}. In addition, 81 trunk lateral tilt toward the support-leg side has been observed in ACL injuries in females^{26–29}. 82Furthermore, the hip adduction angle and abduction moment are positively associated with the 83 knee abduction moment during drop vertical jumping and cutting tasks^{21,24}. Therefore, the 84 importance of controlling trunk and hip biomechanics in the frontal and transverse planes to 85 decrease the knee abduction moment has been emphasized for ACL injury prevention^{11,30,31}. 86 87 While a previous study reported a trend, although not statistically significant, for the hip abduction moment to increase with a subsequent jump following single-leg landing¹³, no study 88 has investigated the effect of subsequent jumping on trunk lateral tilt and rotation motions in 89 the frontal and transverse planes. 90

Trunk and hip biomechanics are associated with the knee abduction moment during 91landings^{11,18–25}. The effects of subsequent jumping after landing on the knee abduction moment 9293and on trunk and hip biomechanics during single-leg landing tasks in females are unclear. It is 94 possible that the change in the knee abduction moment caused by subsequent jumping is 95associated with changes in trunk and hip biomechanics. Understanding the relationships between the change in the knee abduction moment and those in other biomechanics caused by 96 a subsequent jump may be helpful for clinicians to reduce the knee abduction moment during 97 98 a single-leg drop vertical jump. Therefore, the primary purpose of the present study was to investigate the effect of subsequent jumping on the knee abduction moment and on trunk and 99hip biomechanics during single-leg landing tasks in female participants. The secondary purpose 100

101 was to identify the kinetic and kinematic factors associated with the change in the knee 102 abduction moment due to subsequent jumping. The hypotheses were that a subsequent jump 103 would increase the knee abduction moment, trunk lateral tilt and trunk rotation angles and that 104 the change in the knee abduction moment caused by a subsequent jump would be associated 105 with those in the trunk and hip biomechanics.

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Methods

Participants: Thirty female participants (mean \pm SD: age 21.7 \pm 1.7 years; height 159.5 108109 \pm 5.7 cm; weight 52.5 \pm 5.0 kg) volunteered for this study. A priori power analyses in a pilot study with 9 participants showed that 17 participants were necessary to achieve a statistical 110power $(1 - \beta)$ of 0.8 with an alpha level (α) of .05 and an effect size (dz) of .74 in a paired t test 111 112for the knee abduction moment. In addition, a priori power analyses in the pilot study showed that 25 participants were necessary to achieve a statistical power $(1 - \beta)$ of 0.8 with an alpha 113114level (α) of .05 and a coefficient of determination of .26 in a univariate linear regression using the difference in the knee abduction moment between the single-leg drop vertical jumping and 115single-leg drop landing as a dependent variable and that in the hip abduction moment as an 116 117independent variable. The exclusion criteria included a history of musculoskeletal injuries in the previous 6 months, as well as surgeries or fractures in the lower extremities or trunk. All 118 participants had previous experience with regular sports activities (11 tennis, 9 track and field, 1191204 volleyball, 3 badminton, 2 each basketball, handball, sepak takraw, softball, table tennis, karate and ballet, and 1 each soccer, kendo and kickboxing). Some participants had previous 121experience with multiple sports activities. The dominant leg (the side used for kicking a ball), 122123which was the right leg in all participants, was tested and analyzed. Informed consent was obtained from all participants prior to participation in the study. This research was approved by 124125the Institutional Review Board of the Faculty of Health Sciences, Hokkaido University

Procedures: The participants warmed up on a stationary bicycle for 5 minutes. Then, 127the marker coordinate data from each participant were collected during a static standing trial 128to create each participant's model during data processing. After the static standing trial data 129were collected, the participants performed single-leg landing tasks with or without a 130subsequent jump in a random order. All participants were barefoot to exclude the effects of 131shoes on lower extremity kinematics and kinetics³². Single-leg drop landing (SDL) was used 132as the landing task without a subsequent jump (Figure 1a). The participants stood on a 30-133134cm-high box on their dominant leg, then jumped just enough to clear the box before dropping and landing on their dominant leg and landed with their dominant leg on a force plate in the 135SDL task^{11,33,34}. Participants were asked to hold the landing posture for a minimum of 3 136137seconds. Single-leg drop vertical jumping (SDVJ) was used as the landing task with a subsequent jump^{11,12} (Figure 1b). The participants performed the SDVJ task in a similar 138manner to the SDL task; however, they were asked to jump with their dominant leg as high 139and fast as possible immediately after landing. During the two landing tasks, the participants 140were asked to look forward and to keep their hands at ear level to avoid marker occlusion¹¹. 141The participants were allowed to perform practice trials until they became familiar with each 142landing task. Data for three successful trials for each SDL and SDVJ were collected after 143practice trials^{11,12,33,34}. The participants were allowed to rest after each trial, as needed. Failed 144145trials were defined as those in which the nondominant leg touched the ground or the participant lost her balance during the test and were excluded from the analysis. The means 146of three trials for both the SDL and SDVJ tasks were used in the statistical analyses. 147

<u>Data collection</u>: The marker coordinate data were collected with Cortex 5.0.1 (Motion
 Analysis Corporation, Santa Rosa, CA, USA) and seven high-speed cameras (Hawk cameras;
 Motion Analysis Corporation). The ground reaction force data were synchronously collected

with a force plate (Type 9286, Kistler AG, Winterthur, Switzerland). The sampling rates were set to 200 Hz for the marker coordinate data and 1,000 Hz for the force plate data. A total of 41 retroreflective markers were placed on the thigh and shank of the dominant leg, the 7th cervical and 10th thoracic spinous process, the sacrum and both iliac crests, the acromions, the anterosuperior iliac spines, the greater trochanters, the medial and lateral femoral condyles, the medial and lateral malleoli, the heels and the second and fifth metatarsal heads.

157Data analysis: The marker coordinate data and ground reaction force data were low-pass filtered using a zero-lag fourth-order Butterworth filter. The marker coordinate data were low-158pass filtered at 12 Hz^{15,33}, while the ground reaction force was low-pass filtered at 50 Hz to 159evaluate the impulsive knee abduction moment immediately after initial contact³⁵. The trunk, 160hip and knee angles and external moments were calculated in Visual3D software (version 6, C-161162Motion Inc., Germantown, MD, USA) using joint coordinate systems and inverse dynamics. The hip and knee angles were calculated with the Cardan X-Y-Z sequence (i.e., 163flexion/extension, abd-/adduction and internal/external rotation). Positive values indicated 164knee flexion, abduction and internal rotation as well as hip flexion, adduction and internal 165rotation. The trunk angles were calculated as the thorax segment angles in the global coordinate 166system. For the trunk angles, the rotation sequence was changed to Z-Y-X (i.e., axial rotation, 167lateral tilt and anterior/posterior tilt)³⁶. Positive values indicated trunk lateral tilt and rotation 168169toward the support-leg side. The segment anthropometric properties used to determine the external moments were based on a previous report³⁷. The external joint moment was the torque 170caused by an external load. The external knee abduction moment would be resisted by the 171internal knee adduction moment³⁸. Positive external moments indicated knee and hip flexion, 172173abduction and internal rotation. In addition, the vertical ground reaction force was calculated considering the possible association with the knee abduction moment²⁴. All angles measured 174during the static standing trial were set to 0°. The angle and moment data were extracted from 175

the landing phase, which was defined as the time between the initial contact and the maximum knee flexion during both landing tasks. The first landing was analyzed in the SDVJ task. The initial contact was defined as when the vertical ground reaction force first exceeded 10 N³⁹. Peak values of the trunk lateral tilt and rotation; hip flexion, adduction and internal rotation; and knee flexion, abduction and internal rotation angles were calculated during the landing phase. The peak knee and hip flexion, abduction and internal rotation moments and peak vertical ground reaction force during the landing phase were computed.

Statistical analysis: The normality of all values was evaluated using a Shapiro-Wilk test. 183184A paired t test or Wilcoxon signed-rank test was used to investigate the influence of subsequent jumping on the kinematic and kinetic data depending on normality. Univariate regression 185analysis was performed using the differences in trunk, hip, and knee biomechanics and the 186vertical ground reaction force between the SDVJ and SDL tasks as independent variables and 187the difference in the peak knee abduction moment as a dependent variable. The statistical 188analyses were performed using IBM SPSS Statistics, version 26 (IBM, Armonk, NY, USA). 189The level of significance was set to p < .05. In addition, effect sizes were calculated for each 190pairwise comparison with Cohen's dz using G*Power 3.1.9.2 (Institute of Experimental 191Psychology, Hein-rich Heine University, Dusseldorf, Germany). The effect sizes were 192interpreted as follows: $dz \ge .80$ indicated a large effect, $.50 \le dz < .80$ indicated a medium effect, 193and $.20 \le dz < .50$ indicated a small effect⁴⁰. 194

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Results

The peak knee abduction moment was significantly larger during SDVJ than during SDL, with a large effect size (p = .002, dz = .624) (Table 1). In addition, participants exhibited significantly larger peak knee and hip flexion and peak hip abduction moments during SDVJ than during SDL (p < .001, dz = .819; p = .001, dz = .642; p = .008, dz = .517, respectively) 201 (Table 1). There was no other difference in the knee or hip joint moments or the peak vertical202 ground reaction force.

In the kinematic analyses, the peak trunk lateral tilt and rotation angles toward the support-leg side were significantly larger during SDVJ than during SDL (p < .001, dz = .743; p = .031, dz = .413, respectively) (Table 2). Moreover, the peak knee and hip internal rotation angles were significantly larger during SDVJ than during SDL (p = .005, dz = .553; p = .027, dz = .460, respectively) (Table 2). There was no other difference in the trunk, hip and knee kinematics.

Univariate regression analysis showed that the difference in the peak knee abduction moment between SDVJ and SDL was predicted by the difference in the peak hip abduction moment (p = .003, $R^2 = .252$) (Figure 2). The standard regression coefficient (β) was .527. There were no other significant predictors for the difference in the peak knee abduction moment between SDVJ and SDL.

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Discussion

This study revealed that the peak knee and hip abduction moments, the peak trunk lateral tilt and rotation angles toward the support-leg side were significantly larger during SDVJ than during SDL and that the increase in the peak knee abduction moment caused by subsequent jumping was significantly associated with the increase in the peak hip abduction moment. These findings supported the a priori hypotheses.

In the present study, the peak knee abduction moment was significantly larger during SDVJ than during SDL, which is consistent with a previous study on double-leg DVJ and DL^{14,15}. On the other hand, a previous study of a single-leg landing task did not find a significant difference in the knee abduction moment between SDVJ and SDL, although the knee abduction moment during SDVJ was larger than that during SDL¹³. This previous study included 14 male 226and 11 female participants, whereas this study included only female participants. Female athletes have a larger knee abduction moment, normalized for body weight and height, during 227landing than male athletes⁹. The present study was able to detect the difference in the knee 228229abduction moment between the two landing tasks because a sufficient sample size of only female participants were included. Since the effects of a subsequent jump on knee 230biomechanics differed between males and females during double-leg landing tasks¹⁴, future 231studies should investigate sex differences in the effects of a subsequent jump following a single-232leg landing on the knee abduction moment, taking sample size into account. Furthermore, while 233234the participants in the present study had previous experience with regular sports activities regardless of jumping and landing activities, those in the previous study¹³ seemed to be 235recreational athletes participating in jumping and landing sports activities at the time of the 236237study. The difference in participants' characteristics between studies may lead to different result 238in knee abduction moment between the studies.

The difference in the peak knee abduction moment during SDVJ and SDL was 239significantly predicted by the difference in the peak hip abduction moment. In addition, the 240peak knee and hip abduction moments were larger during SDVJ than during SDL. These results 241suggest that the increase in the knee abduction moment caused by a subsequent jump is 242associated with the increase in the hip abduction moment and support previous studies on lateral 243reactive jumping and cutting tasks^{21,25}. Pertinently, the external hip abduction moment is 244245balanced by the internal hip adductor torque. An increase in the trunk lateral tilt toward the support-leg side can generate an external load on the knee abduction moment via the reactive 246hip adductor torque as a result of the increase in the hip abduction moment⁴¹. The peak trunk 247248lateral tilt angle during the SDVJ task was also significantly larger than that during the SDL task in the present study, which may have contributed to the increase in the hip abduction 249moment. However, a causal relationship among these variables cannot be established based on 250

the present study.

Although the difference in the peak hip abduction moment during SDVJ and SDL 252explained 25% of the variance in the difference in the peak knee abduction moment, the 253remaining 75% was not explained. Knee abduction moment is associated with lower gluteus 254medius force during landing²⁴. In addition, gluteus medius and minimus and soleus muscle 255force can resist the knee abduction moment⁴². Moreover, large knee abduction moment during 256single-leg landing is associated with large adductor longus to gluteus medius activity ratio⁴³. 257Muscle force and activity analysis may be required for better prediction, as net moment analysis 258259does not provide individual muscle force or activity.

To the best of our knowledge, the present study is the first to show larger peak trunk 260lateral tilt and rotation angles toward the support-leg side during SDVJ than during SDL. The 261262increase in the trunk lateral tilt and rotation angle toward the support-leg side may be needed 263to position the center of mass closer to the support-leg or to balance the body in preparation for the subsequent jump at maximum height. On the other hand, trunk lateral tilt and rotation 264toward the support-side leg side are reported as signs of weak hip abduction and extension 265strength⁴⁴, and the increase in those motions during SDVJ may be a response to the large 266demand on hip abduction muscle strength to prepare for subsequent jumping⁴⁵. Although a large 267trunk lateral tilt and rotation toward the support-leg side are typically associated with a larger 268knee abduction moment during landing and side cutting tasks^{11,19-23}, linear relationships 269270between the difference in the peak knee abduction moment caused by subsequent jumping and the differences in the trunk lateral tilt and rotation angles were not detected. Trunk lateral tilt 271toward the support-leg side is also a biomechanical feature in ACL injury situations determined 272by video analysis studies $^{26-29}$. Single-leg landing tasks with a subsequent jump, such as SDVJ, 273are similar to ACL injury situations and can be used to evaluate frontal plane trunk control. On 274the other hand, although trunk rotation away from the support-leg side is observed in ACL 275

injury situations^{26,28,29}, large trunk rotation toward the support-leg side is associated with larger
knee abduction moments^{19,21}. Thus, further research is needed to investigate the relationship
between ACL injury and large trunk rotation toward the support-leg side during single-leg
landing tasks with a subsequent jump.

The present study did not find a difference in the knee abduction angle between the SDVJ 280and SDL tasks. This result contradicts prior research, which found that the knee abduction angle 281is larger during landing with a subsequent jump than during landing without a subsequent 282jump^{13,14}. In this study, the peak knee and hip internal rotation angles and flexion moments 283284were significantly larger during SDVJ than during SDL. A previous study reported that larger knee and hip internal rotation angle excursions and smaller knee abduction moment were 285associated with smaller peak knee abduction angles ⁴⁶. In addition, a larger knee flexion moment 286is associated with a larger quadriceps force³⁴, and quadriceps contraction could be used to resist 287knee valgus moments⁴⁷. Moreover, the hip flexion moment (internal hip extension moment) is 288important for modified landing stiffness and is required for soft-landing strategies that are 289associated with a small knee abduction angle^{48,49}. These findings suggest that the increase in 290 the knee and hip internal rotation angles and flexion moments and in the knee abduction 291moment caused by a subsequent jump might be attributed to no change in the knee abduction 292angle caused by a subsequent jump. 293

The present study did not find a difference in the vertical ground reaction force between the two landing tasks. The peak vertical ground reaction forces were comparable between the first and second landings during a double-leg drop vertical jump¹⁵, in which the mid-flight maximum height of center of mass was equivalent between the two landings in a previous study. On the other hand, the peak vertical reaction force during SDVJ was smaller than that during SDL despite the same landing height between the two landings¹³. Additionally, the vertical ground reaction force during the landing phase is not correlated with jumping height in the drop vertical jump task⁵⁰. The peak vertical ground reaction force is usually observed within 63.5
 ms after initial contact during single-leg landing³⁴ and is not associated with subsequent
 jumping after landing.

The present study had some limitations. First, this study included only female 304 participants. Previous studies have reported sex differences in the effects of subsequent jumps 305on knee biomechanics^{13,14}. Therefore, future studies should investigate sex differences in the 306 effects of subsequent jumps after single-leg landings on knee biomechanics while considering 307sample size. Second, only single-leg landings were examined. The kinematic and kinetic factors 308309 associated with an increase in the knee abduction moment caused by subsequent jumps during single-leg landings may differ from those associated with double-leg landings. Third, this study 310included participants of different levels and types of previous sports activities. The level and 311type of sports activities may affect biomechanics during landing^{51,52}. Fourth, participants were 312313asked to keep their hands at ear level during the two landing tasks. Therefore, the effects of the subsequent jump on the landing biomechanics may be different in actual sports situations. Fifth, 314multiple statistical tests were conducted without alpha adjustment in this study. Previous studies 315used similar statistical comparisons of lower extremity kinetics and kinematics with a similar 316 study design^{53,54}. However, we should acknowledge that test repetition increases the probability 317of a studywise type I error rate. Finally, causal relationships among the knee, hip and trunk 318 319biomechanics could not be established based on the associations in this study. The effects of 320intervention on the knee abduction moment should be investigated based on the findings in the present study. 321

The present study showed that a subsequent jump after a single-leg landing led to a significant increase in the knee abduction moment. Moreover, subsequent jumping after a single-leg landing significantly increased the trunk lateral tilt and rotation angles toward the support-leg side and hip abduction moment. The knee abduction moment and trunk lateral tilt

	angle toward the support-leg side were predictive factors of ACL injuries ^{8,55} . A qualitative			
327	assessment tool of single-leg loading included trunk lateral tilt as one of the checklists ⁵⁶ . Thus,			
328	clinicians should use the SDVJ task to evaluate the knee abduction moment, the trunk lateral			
329	tilt and rotation angle. Landing instructions focused on the pelvic and trunk lateral tilt are			
330	effective in reducing the trunk lateral tilt and knee abduction moment during SDVJ ¹¹ .			
331	Furthermore, the change in the peak hip abduction moment caused by a subsequent jump			
332	predicted the change in the peak knee abduction moment in this study. Therefore, controlling			
333	the hip abduction moment (internal hip adductor torque) may be important for decreasing the			
334	knee abduction moment during single-leg landings followed by a subsequent jump. These			
335	findings suggest that landing tasks with a subsequent jump, such as SDVJ, would be more			
336	advantageous for evaluating the knee abduction moment, trunk lateral tilt and rotation angles			
337	and hip abduction moment than landing tasks without subsequent jumping.			
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339	Acknowledgments			
340	The authors would like to thank all participants of this study.			
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	SDVJ	SDL	<i>p</i> value	dz
Peak moment, Nm·kg ⁻¹ ·m ⁻¹				
Hip flexion	2.16 (0.48)	1.91 (0.53)	.001	.642
Hip abduction	0.14 (0.12)	0.09 (0.15)	.008	.517
Hip internal rotation ^a	0.04 (0.06)	0.05 (0.06)	.213	.202
Knee flexion	2.02 (0.31)	1.81 (0.24)	<.001	.819
Knee abduction ^a	0.08 (0.10)	0.05 (0.10)	.002	.624
Knee internal rotation ^a	0.13 (0.08)	0.13 (0.07)	.349	.137
Peak vertical ground reaction force, N/kg	40.1 (4.7)	40.6 (5.0)	.563	.107

Table 1. Comparison of the peak knee and hip joint moments and the peak vertical ground 520reaction force between SDVJ and SDL. 521

522SDVJ: single-leg drop vertical jumping, SDL: single-leg drop landing.

The data are presented as the mean (SD). 523

Knee and hip moments are calculated as external joint moments. 524

525^anon-parametric data.

526

	SDVJ	SDL	<i>p</i> value	dz
Peak angle, degree				
Trunk lateral tilt	5.7 (3.2)	4.3 (2.6)	<.001	.743
Trunk rotation	4.9 (3.8)	3.6 (4.3)	.031	.413
Hip flexion	34.5 (6.4)	36.3 (6.3)	.053	.369
Hip adduction	9.4 (4.2)	9.1 (3.6)	.596	.098
Hip internal rotation ^a	7.4 (5.6)	6.3 (4.7)	.027	.460
Knee flexion	59.2 (6.6)	59.2 (7.1)	.940	.014
Knee abduction	0.3 (4.2)	-0.2 (3.2)	.143	.275
Knee internal rotation	7.8 (5.3)	6.8 (5.9)	.001	.553

527 **Table 2**. Comparison of the peak knee, hip and trunk kinematics between SDVJ and SDL

528 SDVJ: single-leg drop vertical jumping, SDL: single-leg drop landing.

529 The data are presented as the mean (SD).

530 Bold font indicates a significant difference (p < .05).

531 Positive angles indicated trunk lateral tilt and rotation toward the support-leg side.

532 ^anon-parametric data.

533

534

Figure Captions

Figure 1. Landing tasks with and without a subsequent jump. Single-leg drop landing (SDL): the participants stood on a 30-cm-high box on their dominant leg, then jumped just enough to clear the box before dropping and landing on their dominant leg and landed on a force plate (a). Single-leg drop vertical jumping (SDVJ): the participants stood on a 30-cm-high box on their dominant leg, then jumped just enough to clear the box before dropping and landing on their dominant leg, landed on a force plate, and executed a maximum single-leg vertical jump immediately after landing (b).

542

Figure 2. Scatter plot of the association of the between-task difference in the peak knee
abduction moment with the between-task difference in the peak hip abduction moment. The
between-task difference was determined by subtracting the SDL value from the SDVJ value.
Knee and hip abduction moments are calculated as external joint moments.



