

# Influence of a Full-Body Compression Suit on Trunk Positioning and Knee Joint Mechanics During Lateral Movements

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### 23 Abstract

24 Trunk positioning has been shown to be associated with knee joint loading during athletic tasks, especially changes of direction. The purpose of the present study was to test whether a full body 25 26 compression suit (FBCS) would improve trunk positioning and knee joint control during lateral movements. Twelve female athletes performed lateral reactive jumps (LRJ) and unanticipated 27 cuttings with and without the customized FBCS, while 3D kinematics and kinetics were 28 29 measured. FBCS did not influence trunk positioning during LRJ and led to increased trunk 30 lateral lean during cuttings (P < .001). However, while wearing FBCS, knee joint abduction and internal rotation angles were reduced during LRJ (P < .001 and P = .013, respectively), 31 32 whereas knee joint moments were comparable during cuttings. FBCS cannot support the trunk segment during unanticipated dynamic movements. But increased trunk lateral lean during 33 34 cutting maneuvers was not high enough to elicit increased knee joint moments. On the contrary, 35 knee joint abduction and internal rotation were reduced during LRJ, speaking for a better knee joint alignment with FBCS. Athletes seeking to improve trunk positioning may not benefit from 36 37 a full body compression suit.

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39 *Keywords:* cuttings, perturbation, trunk lateral lean, knee abduction moment, agility.

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41 Word Count: 3995 words

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#### Introduction

44 Lateral movements with changes of direction are common in many team sports such as soccer or handball. During cutting maneuvers, the athlete performs a complex dynamic task by 45 46 quickly changing their direction of movement while securing their balance. Knee joint control is an essential requirement during such movements to prevent misalignments in the lower 47 extremities with the consequence that the knee may be injured.<sup>1,2</sup> Non-contact anterior cruciate 48 49 ligament (ACL) injury mechanism during cutting maneuvers typically involves knee external flexion moment combined with dynamic valgus rotation with the body weight shifted over the 50 injured leg.<sup>2</sup> Trunk positioning during lateral movements is of interest as it would influence the 51 location of the body weight, and potential knee joint loads.<sup>3,4</sup> Hewett and Myer<sup>3</sup> proposed a 52 knee injury model that accounted for both the trunk and hip joints, because increased trunk 53 54 lateral lean is reportedly associated with larger external knee abduction moments. Greater 55 lateral trunk position has been shown during anterior cruciate ligament injury situations in female athletes.<sup>5</sup> Different laboratory studies using cutting maneuvers and lateral reactive jumps 56 57 paradigms have demonstrated that increased trunk lateral lean is positively associated with increased knee abduction moments.<sup>6–8</sup> Further, increased knee joint loading has been associated 58 with increased trunk rotation away from the stance limb.<sup>8,9</sup> For instance, higher knee internal 59 rotation moment was found for trunk rotation in the opposite direction to the cutting maneuver.<sup>8</sup> 60 61 Accordingly, any improvement of trunk positioning is of interest with regard to knee joint loading. This would be especially true for female athletes, whose incidence of ACL injuries in 62 sports such as soccer and basketball is much higher than male athletes.<sup>10,11</sup> 63

In sport sciences, the influence of compression garments, providing passive support to different body segments during exercise has been extensively studied.<sup>12</sup> It has been showed that compressive and elastic garments could reduce the range of motion of the joint.<sup>13,14</sup> Compression shorts reduced the active range of motion during hip flexion in a non-athletic

task<sup>13</sup> and hip range of motion during a 60 m sprint.<sup>14</sup> Wearing shorts with directional 68 compression was associated with reduced hip adductor activity during cutting manoeuvres.<sup>15</sup> In 69 this latter study, the use of diagonal bands of fabric that only stretch along their length increased 70 71 the compression level along the line of action of hip adductors. Therefore, apparel, through their compression and elasticity properties, could be used to passively support body segments and 72 73 joints during various tasks. A compression suit that would functionally support the trunk over 74 the pelvis and leg could be a solution to avoid trunk positioning in the opposite direction to the intended movement. Such apparel would work as external trunk stabilizers to improve trunk 75 positioning during various tasks, especially lateral movements, and subsequently possibly 76 77 reduce knee joint loading.

In sports, any improvement of movement control would further be relevant if associated with enhanced performance. However, when considering whole-body dynamic tasks, wearing a compression suit did not influence performance in cricket players<sup>16</sup> or endurance performance during running.<sup>17</sup> Only one study has shown possible benefits of a whole-body compression garment on performance during high intensity intermittent exercises, mainly because of better muscle oxygenation.<sup>18</sup> Therefore, athletic performance is not likely to be increased when using garments.

85 The aim of this present study was to test whether compression garments can improve trunk and hip positioning and resultant knee joint loading, while not decreasing performance 86 during dynamic lateral sporting movements. For that purpose, a full body compression suit with 87 functional elastic straps was designed to improve trunk positioning and knee joint control 88 89 during lateral movements. We tested the hypotheses that i) trunk and hip joint angles would be 90 reduced with the compression suit, ii) knee joint abduction moment would be reduced with the 91 compression suit and iii) exercise performance level would be maintained while wearing the 92 compression suit.

#### Methods

94 According to other studies evaluating comparable dependent measures during unanticipated lateral movements<sup>19</sup> or the influence of compression shorts on sports 95 performance,<sup>13</sup> a sample size of 13 participants was estimated relevant for statistical analysis. 96 The rationale for focusing on females was their relative higher risk of sustaining non-contact 97 ACL injuries.<sup>10</sup> Among the 13 female athletes recruited to participate to the study, one was 98 99 injured during a training session with her team during the investigation period and could not 100 take part in the measurements. Therefore, 12 female athletes (body height =  $171 \pm 4$  cm; body 101 mass =  $59 \pm 4$  kg; age =  $22 \pm 2$  years) who were familiar with lateral movements (soccer, 102 basketball and handball) completed the entire study. Participants did not have a previous history 103 of serious knee injury or any current knee pain. Written consent was obtained prior to study 104 participation. The study was approved by the local ethics committee (approval 72/14) and was 105 conformed to requirements stipulated in the Declaration of Helsinki.

106 During a first visit, participants' body dimensions were scanned (BodyKinectizer, 107 adidas IT Innovation, Herzogenaurach, Germany), in order to customize the full body 108 compression suit. During a second visit at our laboratory, participants performed different 109 lateral movements and performance tests under two different apparel conditions, either while 110 wearing the customized full body compression suit (FBCS) with 2x thermoplastic polyurethane 111 (TPU) layers or with standard sport shorts and bras (Control). FBCS was a prototype specially 112 designed for the present study in order to provide support for the trunk over the pelvis segment 113 in three dimensions. For that purpose, a mean compression level of 5.2 mmHg was achieved 114 and the 2x TPU layers design linked the upper body with lower limbs across the pelvis in the 115 back (Figure 1). The compression level was first determined for elastic and TPU fabrics 116 separately, according to their relative stretch and then averaged over the whole suit. At specific 117 points, the compression level was even greater, for instance at the low waist and thigh lines (8.3

118 and 6.7 mmHg, respectively). By determining the compression exactly and creating a 119 customized suit for each subject, identical apparel conditions were guaranteed for all subjects, and the possible effectiveness of the compressive suit was measurable.<sup>20</sup> To determine to what 120 121 extent wearing FBCS would influence trunk range of motion, trunk passive flexibility in frontal and sagittal planes was measured according to the literature.<sup>21</sup> In addition, trunk rotation passive 122 123 flexibility was evaluated while participants lay on their backs with the right bent knee crossing 124 over the thigh of the left extended leg. Participants remained relaxed and kept their back and 125 both shoulders in contact with the floor, while the distance between the floor and knee was 126 measured. Reduced mean trunk passive flexibility over all participants was obtained with FBCS 127 compared to Control for flexion (2.2 cm) and rotation (2 cm), but was comparable for lateral 128 flexion.

The two conditions were randomly assigned over all participants. According to pilot measurements, participants were given 30 minutes to become accustomed to the suit. During this period, standardized exercises were carried out based on runs, jumps and cuttings. When subjects started the measurement with FBCS, another 30 minutes practice was given to them prior to the Control condition.

134 Firstly, participants performed perturbed lateral reactive jumps (LRJ) to focus on the 135 influence of FBCS on movement control during a functional task associated with high trunk 136 lateral lean in the frontal plane. From a standing position, subjects performed a lateral reactive movement by jumping to their left side and then pushing off with their left leg to get back to 137 138 their original position. Jump distance was set at 124% of the individual leg length. In order to 139 induce lateral perturbations, subjects performed LRJ on a motor-driven plate, which could 140 translate in the horizontal (medio-lateral) direction. The specially designed motor-driven plate 141 (University of Sport Science, Freiburg, Germany) constituted of two independently moving plates (1.15 m x 0.3 m), each driven by a separate motor (AKM51G, Danaher Motion, 142

Düsseldorf, Germany). Details of this material have been previously described in the 143 literature.<sup>22</sup> LRJ were performed, either without any perturbation (stable condition), or with a 144 perturbation to the left (sliding condition) or to the right (counteracting condition) as soon as 145 146 the foot made initial contact with the plate. Each perturbation consisted of a 10 cm translation in either direction over 250 ms, inducing a peak velocity of 0.55 m.s<sup>-1</sup> after 120 ms. 147 148 Unpredictability was introduced using these three different landing modalities (stable, sliding, 149 counteracting) that were unknown prior to movement execution. Perturbation was triggered by 150 breaking a light beam (M18 series, Panasonic Electric Works Europe AG, Holzkirchen, 151 Germany), 0.04 m above the plate, to compensate for the delay in activation of the motor-driven 152 plate.

Secondly, participants were asked to perform either cutting maneuvers to 45°, 153 crossovers to -20° or straight runs on a force plate (BP600900, AMTI®, Watertown, USA), 154 155 after approaching the force plate (FP) at  $4 \pm 0.2$  m.s<sup>-1</sup>. The direction of the movement was 156 indicated in a randomized order by a light signal occurring 650 ms before the left foot contacted 157 the FP. The visual light stimulus was triggered automatically during the approach run via a light 158 switch (M18 series, Panasonic Electric Works Europe AG, Holzkirchen, Germany) placed 3.7 159 m from FP. According to a light cue delay set individually, the 650 ms time could be achieved. 160 The three lights were placed at eye level in the directions of the three tasks, 7 m away from the 161 FP. The 45° cutting maneuver to the right was the only movement to be further analyzed due to its relevance when investigating performance and injury aspects of changing direction tasks. 162 163 Finally, three different performance tests were conducted to evaluate agility with the 5-164 10-5 yards test, jump height, i.e. leg muscle power, with counter movement jumps (CMJ) and 165 core strength with a cable lift test. This latter test targets the action of hips, torso rotators, upper 166 back, chest and shoulders while turning the trunk away from the strength machine as the hands 167 first pull the rope cable handle towards the chest and then push up and away. The rationale for these tests is the importance of agility, leg muscle power and core strength for high performance during soccer, basketball or handball games. The good reliability of jump height measurements during CMJ has been reported in the literature (intraclass correlation coefficient (ICC) = 0.9),<sup>23</sup> as well as for the 5-10-5 yards agility test (ICC > 0.87).<sup>24</sup> The time to accomplish the agility test was measured manually. Two CMJ were performed on the FP. The cable lift test was conducted twice at 70% of one-repetition maximum.

174 All participants were familiar with such movements due to their sport practice and were 175 given enough practice trials to feel comfortable with all task modalities prior to the 176 measurements.

177 Three-dimensional leg kinematics were recorded using reflective skin markers ( $\emptyset$  14 mm) placed on anatomical landmarks of the subjects' trunk (three markers), pelvis (four 178 179 markers) and left thigh (three markers), shank (four markers) and foot (six markers). Markers were captured with a 12-camera motion analysis system (Vicon MX<sup>TM</sup>, VICON Motion 180 Systems Ltd.®, Oxford, UK) with a sampling frequency of 200 Hz. A static trial with the 181 182 subject standing in a pre-defined neutral position was used to define the kinematic model and 183 to calculate segment lengths and joint centers. The kinematic modelling was performed with 184 the motion analysis software (Vicon Nexus 1.6.1, VICON Motion Systems Ltd.®, Oxford, 185 UK). Joint kinematics in three rotational degrees of freedom were determined using an yxz Euler rotation sequence of the respective segment coordinate system according to the global 186 187 reference system defined in Vicon. This rotation sequence was around the flexion/extension axis first, then around the abduction/adduction axis followed by the rotation around the 188 189 external/internal axis. This marker placement and kinematic modelling were used in previously published articles.<sup>7,19</sup> 190

Marker trajectory and ground reaction force signals were both filtered with a low pass
Butterworth filter (4<sup>th</sup> order, 15 Hz cut-off frequency) prior to calculating external joint

193 moments with a standard inverse dynamics approach. Three-dimensional kinematic data of the 194 trunk segment and hip joint were analyzed to understand the influence of FBCS on trunk positioning. Three-dimensional kinematics and kinetics of the knee joint were further analyzed 195 196 to determine the influence of FBCS on knee joint stability and loading. Both kinematics and 197 kinetics were measured during cutting maneuvers, but only kinematics was observed during 198 LRJ. These variables were analyzed at the time of their peak values during the first half of 199 ground contact during LRJ, to give some insights into how the apparel condition influences the 200 range of motion of the different body segments. However, during cutting maneuvers, the 201 different variables were determined at the time of peak knee abduction moment, as this is a relevant parameter associated with knee injury.<sup>25</sup> 202

Trunk lateral lean and trunk axial rotation were defined relative to the global coordinate system, i.e. deviations from the vertical axis and from the anterior-posterior axis, respectively. Both were positive for an orientation in the new movement direction (i.e. to the right direction). Hip rotation, knee rotation and knee rotation joint moment were defined as positive for an external rotation.

The time to accomplish the 5-10-5 yards test served as outcome measure for agility. CMJ height was calculated based on the flight time method. During cable lift testing, the vertical acceleration signal of the accelerometer (University of Sport Science, Freiburg, Germany) placed on the top of the weight stack was filtered with a low pass Butterworth filter (4<sup>th</sup> order, 20 Hz cut-off frequency) and then integrated to obtain velocity. Based on Newton's second law, lift force was calculated. Finally, power was determined by means of the product of force and velocity.

The selected parameters were averaged across eight trials for the different LRJ modalities and the 45° cutting maneuver, while the time during the 5-10-5 yards test was reported, and the highest CMJ and mean peak power value over two cable lift trials were 218 calculated. These parameters served as the basis for the statistical analysis (Statistica 12, 219 StatSoft, Inc.<sup>®</sup>, Tulsa, OK, US). All results are presented as group mean ± standard deviation (SD). After having confirmed that data followed a normal distribution (Shapiro-Wilk W), 220 221 sphericity was verified by means of the Mauchly's test. The influence of the apparel condition on dependent variables for LRJ modalities was calculated using a two-way analysis of variance 222 223 (General Linear Model) with repeated measures to test for main effects of and interactions 224 between apparel (Control vs. FBCS) and LRJ modality (stable vs. sliding vs. counteracting). If 225 a statistically significant LRJ modality main effect was observed, Bonferroni corrected paired comparisons determined where the differences occurred. The influence of the apparel condition 226 227 (Control vs. FBCS) on the dependent variables for the cutting maneuver and performance tasks 228 was analyzed using paired two-tailed t-tests. The magnitude of the changes was assessed with 229 effect size (ES) and 95% confidence interval (CI). The ES was evaluated by means of partial eta squared  $(\eta^2_p)$  values and were considered small (.01 - .06), medium (.06 - .14) and large 230 (>.14) according to Cohen<sup>26</sup>. The level of significance was set at P < .05. 231

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#### **Results**

233 There was a significant main effect of the apparel condition on hip rotation, knee 234 abduction and rotation during LRJ (Table 1). Hip joint internal rotation was increased with 235 FBCS (P = .019), while knee joint abduction and internal rotation were reduced (P = .002 and 236 P < .001, respectively). Statistical analysis revealed a significant main effect of the LRJ modality on trunk forward lean and trunk lateral lean (P = .025 and P = .003, respectively), hip 237 flexion, abduction and rotation (P < .001 for all), knee flexion and rotation (both P < .001). 238 239 However, no interaction effect (apparel condition x LRJ modality) was reported. Specifically, pairwise comparisons revealed that stable, sliding and counteracting modalities yielded 240 241 significantly different values from each other for trunk lateral lean (P < .004 for all), hip flexion (P < .001 for all), hip rotation (P < .003 for all), knee flexion (P < .001 for all) and knee rotation 242

243 (P < .003 for all). Trunk flexion was significantly greater during counteracting than both stable 244 (P < .02) and sliding (P < .001). Hip abduction was significantly greater during sliding than 245 both stable (P < .001) and counteracting (P < .001).

During the cutting maneuver, trunk forward lean and axial rotation were not influenced by the apparel condition at the time of peak knee abduction moment, while trunk lateral lean was significantly increased by FBCS (P < .001). Hip joint internal rotation was higher for FBCS than Control (P = .003). Knee joint angles and moments, especially the knee abduction moment, were not influenced by the apparel condition (Table 2). The ensemble averages of trunk lateral lean and knee joint abduction moment over the stance phase of the cutting maneuver are presented (Figure 2).

Performance parameters were not significantly influenced by the apparel condition. The sprint time measured during the 5-10-5 yards test was comparable between the two apparel conditions ( $5.6 \pm 0.3$  s for both conditions; P = .90, 95% CI [-0.15, 0.13],  $\eta^2_p = .002$ ). CMJ height was not significantly different between Control and FBCS conditions ( $0.28 \pm 0.05$  m for both; P = .40, 95% CI [-0.01, 0.01],  $\eta^2_p = .07$ ). Mean peak power produced by the participants during the cable lift did not differ significantly (P = .55, 95% CI [-6, 11],  $\eta^2_p = .03$ ) when performing the movement in the Control condition ( $282 \pm 69$  W) or with FBCS ( $280 \pm 68$  W).

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#### Discussion

The main findings of the study were as follows: 1) FBCS did not reduce trunk angles during lateral movements, with even an increased trunk lateral lean during cutting maneuvers; 2) hip internal rotation was increased with FBCS; 3) knee joint moments were not reduced with FBCS; and 4) performance level was kept at the same level.

266 Perturbed lateral reactive jumps yielded significantly different segment and joint 267 configurations at the time of their peak values. A detailed analysis of the influence of LRJ

modality at the time of initial contact has already been provided in the literature.<sup>27</sup> But during 268 269 perturbed lateral reactive jumps, trunk positioning was not influenced by the compression garment. It seems that despite a suit design enabling a reduced passive trunk range of motion, 270 271 FBCS cannot support the trunk segment during an active dynamic movement. Thus, the trunk segment was not supported either during cutting maneuvers. On the contrary, trunk lateral lean 272 was even significantly increased by 4° while wearing FBCS during 45° cutting maneuvers. 273 274 While all participants showed greater trunk lateral lean with FBCS than without apparel, five 275 subjects reached particularly large values around 15° with FBCS. Although literature demonstrated that compression garments could reduce the active range of motion of the hip 276 joint during a non-athletic task<sup>13</sup> and during sprinting,<sup>14</sup> a more neutral trunk positioning 277 278 through apparel could not be achieved during unanticipated lateral movements. It might be possible that participants would rely on the support of the suit according to the compression 279 280 and elasticity properties felt by the participants, thereby reducing their active trunk muscle 281 control. But the lack of apparel support would bring participants to this higher trunk lateral lean 282 in the frontal plane during cutting maneuvers.

The specific FBCS linked shoulders with knees across the pelvis in the back thanks to the elastic straps design. But at the hip joint level, only hip internal rotation was altered. The hip internal rotation observed in the present study is consistent with literature during lateral reactive jumps<sup>27</sup> and cutting manoeuvres.<sup>28</sup> However, increased peak internal rotation values with FBCS might rather reflect a lack of strength in the external hip rotators in female athletes,<sup>29</sup> exacerbated by the additional tension of the compression garment.

It appears that external passive support with the aim of enhancing trunk positioning during dynamic lateral movements classically encountered during team sports is difficult to achieve with apparel. At this point, further improvements to the design of the compression suit does not seem possible as several years of research and development were needed to yield this current comfortable full-body suit, which enables reduced passive trunk flexibility through the combined compression and elasticity properties. In addition, garments were customized to each participant in the present study. Further increasing the compression level of the suit to further support body segments, i.e. by reaching typical values of compression socks > 15 mmHg,<sup>30</sup> does not seem possible given that i) the straps used already increase the stiffness of the suit and ii) the higher compression level would reduce the comfort level necessary to perform wholebody dynamic movements.

300 Trunk and hip control alterations with FBCS could have consequences at the knee joint level. Indeed, higher trunk lateral lean during cutting maneuvers while wearing FBCS might be 301 associated with increased knee joint loading.<sup>6,7</sup> In present study, higher trunk lateral lean had 302 303 no deleterious influence on the knee joint, as no significant difference in knee abduction 304 moment was evident between FBCS and control conditions. Increased peak internal hip rotation angles with FBCS might reflect a lack of strength in the external hip rotators<sup>29</sup> and further a 305 306 critical knee joint position (position of no return), where the hip moves more rapidly into adduction and internal rotation and the knee collapses in valgus.<sup>31</sup> But the consequences at the 307 308 knee joint level during lateral reactive jumps were rather a reduction of the abduction and internal rotation angles whatever the landing condition with FBCS which speaks in favor of 309 310 better knee joint alignment. Thus, alteration of trunk positioning during lateral movements with 311 FBCS was not associated with changes in knee joint stability.

This result does not support the theoretical model proposed by Hewett and Myer<sup>3</sup> and is not in agreement with experimental results, where increased trunk lateral lean was associated with increased knee joint abduction moment.<sup>6,7</sup> This finding underlines the fact that trunk positioning only partially influences knee joint loading, and that relatively small trunk angle variations (4°), albeit significant, may not always have an effect on knee abduction moment, especially when considering the large variability of this knee joint loading parameter.

It is worth noticing that FBCS had no influence on any of the performance parameters. 318 319 The same level of agility while wearing the compression suit or in the control condition during the 5-10-5 yards test is consistent with the literature.<sup>13,16,32</sup> Although improvement of jumping 320 performance with a compression garment has been reported in the literature,<sup>14,33</sup> it is interesting 321 322 to note that jump height was not impaired with the compression suit targeting trunk and pelvis 323 positioning rather than the lower limbs in the present study. Finally, core strength during the 324 cable lift task was kept at the same level when performed with FBCS. Accordingly, FBCS can 325 be used by athletes without risk of compromising performance.

326 This study has some limitations that need to be considered. The moderate reliability of 327 knee kinetics during dynamic tasks such as cutting tasks would suggest the need for a greater sample size than 12 participants.<sup>34</sup> In the present study, measured variables were assessed over 328 329 eight trials to ensure representative values for each participant. But the inter-subject variability 330 was pretty high for joint kinetics and the associated statistical power low (< 0.2). Thus, future 331 studies would possibly need a larger sample size to tease out effects on knee joint kinetics or at 332 least enable to discuss the lack of difference in knee joint loading. Another potential limitation 333 was the use of a cable lift task. While this test seems to be relevant to evaluate core strength, 334 the validity and reliability of this measure would need to be assessed to determine its 335 measurement error. This will allow evaluating the importance of observed differences from a 336 statistical perspective as well as in terms of its practical implication.

Even if compression and elasticity properties were combined with this customized full body compression suit, trunk kinematics could not be favorably influenced. Achieving external support of trunk positioning in female athletes through apparel seems to be difficult during unanticipated lateral movements. However, a full body compression suit did not impair any of the performance parameters and even yielded a better alignment of the knee during lateral reactive jumps.

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## Tables

**Table 1** Mean  $\pm$  SD values of the different kinematic variables during lateral reactive jumps (LRJ) performed in Control and full body compressionsuit (FBCS) conditions.

Variable	Control (pooled LRJ)	FBCS (pooled LRJ)	P value	95% CI	ES ( $\eta^2_p$ )
Trunk Forward Lean (°)	$32.0\pm 6.2$	$31.6\pm6.8$	.66	[-1.7, 2.5]	.02
Trunk Lateral Lean (°)	$-7.5 \pm 5.4$	$-7.9 \pm 6.1$	.63	[-1.4, 2.2]	.02
Trunk Right Axial Rotation (°)	$4.6\pm9.4$	$6.7\pm9.3$	.10	[-4.7, 0.5]	.23
Hip Flexion (°)	$50.6\pm8.9$	$51.1 \pm 13.3$	.84	[-5.5, 4.5]	<.01
Hip Abduction (°)	$35.5\pm4.7$	$35.7\pm5.7$	.84	[-2.5, 2.0]	< .01
Hip Ext. Rotation (°)	$-5.0 \pm 6.5$	$-11.1 \pm 6.2*$	.019	[1.2, 10.9]	.41
Knee Flexion (°)	$59.0\pm5.3$	$59.9\pm5.1$	.10	[-2.0, 0.2]	.23
Knee Abduction (°)	$10.3\pm6.7$	$5.3 \pm 3.9 **$	.002	[2.3, 7.5]	.61
Knee Ext. Rotation (°)	$-13.5 \pm 7.4$	$-8.6 \pm 6.5^{***}$	<.001	[-7.3, -2.6]	.66

The influence of the apparel condition is reported using *P*, 95% confidence interval (95%CI) and effect size (ES) with partial eta squared ( $\eta^2_p$ ) values.

\*, \*\*, \*\*\* indicates significant differences between Control and FBCS with P < .05, P < .01 and P < .001, respectively.

**Table 2** Mean  $\pm$  SD values of the different kinematic and joint moment variables during cutting maneuvers performed in Control and full bodycompression suit (FBCS) conditions.

Variable	Control	FBCS	<i>P</i> value	95% CI	ES ( $\eta^2_p$ )
Trunk Forward Lean (°)	$12.6\pm7.8$	$13.9\pm5.6$	.22	[-3.6, 0.9]	.14
Trunk Lateral Lean (°)	$-5.1 \pm 3.7$	$-8.7 \pm 5.0$ ***	<.001	[2.2, 5.0]	.74
Trunk Right Axial Rotation (°)	$-8.5 \pm 8.4$	$-7.8\pm7.5$	.61	[-3.4, 2.1]	.02
Hip Flexion (°)	$51.6\pm6.7$	$49.3 \pm 10.6$	.35	[-2.9, 7.5]	.08
Hip Abduction (°)	$8.4\pm8.9$	$7.7\pm5.9$	.59	[-2.2, 3.7]	.03
Hip Ext. Rotation (°)	$-4.2 \pm 7.3$	$-9.8 \pm 4.4 ^{**}$	.003	[2.4, 8.8]	.57
Knee Flexion (°)	$28.3\pm5.0$	$28.0\pm 6.1$	.56	[-0.9, 1.6]	.03
Knee Abduction (°)	$4.7\pm3.1$	$2.7\pm3.1$	.054	[-0.1, 4.1]	.30
Knee Ext. Rotation (°)	$-7.4\pm6.6$	$-3.4 \pm 5.2$	.052	[-8.1, 0.1]	.30
Knee Flexion Moment (Nm.kg <sup>-1</sup> )	$0.16\pm0.65$	$0.20\pm0.75$	.74	[-0.33, 0.24]	.01
Knee Abduction Moment (Nm.kg <sup>-1</sup> )	$1.31\pm0.46$	$1.20\pm0.46$	.30	[-0.12, 0.35]	.1
Knee Ext. Rotation Moment (Nm.kg <sup>-1</sup> )	$-0.13\pm0.11$	$-0.16\pm0.12$	.42	[-0.06, 0.13]	.06

The influence of the apparel condition is reported using *P*, 95% confidence interval (95%CI) and effect size (ES) with partial eta squared ( $\eta^2_p$ ) values.

\*\*\*, \*\*\* indicates significant differences between Control and FBCS with P < .01 and P < .001, respectively.

### **Figure Captions**

**Figure 1** - Participant wearing the customized full body compression suit (FBCS) with 2x thermoplastic polyurethane layers (TPU). The FBCS design provides support for the trunk over the pelvis segment through the 2x TPU layers that link the upper body with lower limbs across the pelvis in the back (right). The customized apparel production ensures a perfect fitting for each participant.

**Figure 2** - Ensemble averages of lateral trunk flexion in the frontal plane and knee joint abduction moment for Control (black line) and full body compression suit (FBCS, grey line) during the foot contact phase of the cutting maneuver.