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4 Influence of a full body compression suit on trunk positioning and knee joint mechanics  
5 during lateral movements.

6

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13

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21 **Running Title:** Full body compression suit and lateral movements.

22

23 **Abstract**

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

38

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

40

41 **Word Count:** 3995 words

42

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## Introduction

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

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

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

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

85         The aim of this present study was to test whether compression garments can improve  
86 trunk and hip positioning and resultant knee joint loading, while not decreasing performance  
87 during dynamic lateral sporting movements. For that purpose, a full body compression suit with  
88 functional elastic straps was designed to improve trunk positioning and knee joint control  
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.

93

## Methods

94 According to other studies evaluating comparable dependent measures during  
95 unanticipated lateral movements<sup>19</sup> or the influence of compression shorts on sports  
96 performance,<sup>13</sup> a sample size of 13 participants was estimated relevant for statistical analysis.  
97 The rationale for focusing on females was their relative higher risk of sustaining non-contact  
98 ACL injuries.<sup>10</sup> Among the 13 female athletes recruited to participate to the study, one was  
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,  
120 and the possible effectiveness of the compressive suit was measurable.<sup>20</sup> To determine to what  
121 extent wearing FBCS would influence trunk range of motion, trunk passive flexibility in frontal  
122 and sagittal planes was measured according to the literature.<sup>21</sup> In addition, trunk rotation passive  
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.

129         The two conditions were randomly assigned over all participants. According to pilot  
130 measurements, participants were given 30 minutes to become accustomed to the suit. During  
131 this period, standardized exercises were carried out based on runs, jumps and cuttings. When  
132 subjects started the measurement with FBCS, another 30 minutes practice was given to them  
133 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  
137 movement by jumping to their left side and then pushing off with their left leg to get back to  
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  
142 plates (1.15 m x 0.3 m), each driven by a separate motor (AKM51G, Danaher Motion,

143 Düsseldorf, Germany). Details of this material have been previously described in the  
144 literature.<sup>22</sup> LRJ were performed, either without any perturbation (stable condition), or with a  
145 perturbation to the left (sliding condition) or to the right (counteracting condition) as soon as  
146 the foot made initial contact with the plate. Each perturbation consisted of a 10 cm translation  
147 in either direction over 250 ms, inducing a peak velocity of 0.55 m.s<sup>-1</sup> after 120 ms.  
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.

153 Secondly, participants were asked to perform either cutting maneuvers to 45°,  
154 crossovers to -20° or straight runs on a force plate (BP600900, AMTI®, Watertown, USA),  
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  
162 to its relevance when investigating performance and injury aspects of changing direction tasks.

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



168 these tests is the importance of agility, leg muscle power and core strength for high performance  
169 during soccer, basketball or handball games. The good reliability of jump height measurements  
170 during CMJ has been reported in the literature (intraclass correlation coefficient (ICC) = 0.9),<sup>23</sup>  
171 as well as for the 5-10-5 yards agility test (ICC > 0.87).<sup>24</sup> The time to accomplish the agility  
172 test was measured manually. Two CMJ were performed on the FP. The cable lift test was  
173 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 ( $\varnothing$  14  
178 mm) placed on anatomical landmarks of the subjects' trunk (three markers), pelvis (four  
179 markers) and left thigh (three markers), shank (four markers) and foot (six markers). Markers  
180 were captured with a 12-camera motion analysis system (Vicon MX<sup>TM</sup>, VICON Motion  
181 Systems Ltd.®, Oxford, UK) with a sampling frequency of 200 Hz. A static trial with the  
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  
186 Euler rotation sequence of the respective segment coordinate system according to the global  
187 reference system defined in Vicon. This rotation sequence was around the flexion/extension  
188 axis first, then around the abduction/adduction axis followed by the rotation around the  
189 external/internal axis. This marker placement and kinematic modelling were used in previously  
190 published articles.<sup>7,19</sup>

191 Marker trajectory and ground reaction force signals were both filtered with a low pass  
192 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  
195 positioning. Three-dimensional kinematics and kinetics of the knee joint were further analyzed  
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  
202 relevant parameter associated with knee injury.<sup>25</sup>

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

208 The time to accomplish the 5-10-5 yards test served as outcome measure for agility.  
209 CMJ height was calculated based on the flight time method. During cable lift testing, the  
210 vertical acceleration signal of the accelerometer (University of Sport Science, Freiburg,  
211 Germany) placed on the top of the weight stack was filtered with a low pass Butterworth filter  
212 (4<sup>th</sup> order, 20 Hz cut-off frequency) and then integrated to obtain velocity. Based on Newton's  
213 second law, lift force was calculated. Finally, power was determined by means of the product  
214 of force and velocity.

215 The selected parameters were averaged across eight trials for the different LRJ  
216 modalities and the 45° cutting maneuver, while the time during the 5-10-5 yards test was  
217 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.®, Tulsa, OK, US). All results are presented as group mean  $\pm$  standard deviation  
220 (SD). After having confirmed that data followed a normal distribution (Shapiro-Wilk W),  
221 sphericity was verified by means of the Mauchly's test. The influence of the apparel condition  
222 on dependent variables for LRJ modalities was calculated using a two-way analysis of variance  
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  
226 comparisons determined where the differences occurred. The influence of the apparel condition  
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  
230 eta squared ( $\eta^2_p$ ) values and were considered small (.01 - .06), medium (.06 - .14) and large  
231 ( $> .14$ ) according to Cohen<sup>26</sup>. The level of significance was set at  $P < .05$ .

232

## 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  
237 modality on trunk forward lean and trunk lateral lean ( $P = .025$  and  $P = .003$ , respectively), hip  
238 flexion, abduction and rotation ( $P < .001$  for all), knee flexion and rotation (both  $P < .001$ ).  
239 However, no interaction effect (apparel condition x LRJ modality) was reported. Specifically,  
240 pairwise comparisons revealed that stable, sliding and counteracting modalities yielded  
241 significantly different values from each other for trunk lateral lean ( $P < .004$  for all), hip flexion  
242 ( $P < .001$  for all), hip rotation ( $P < .003$  for all), knee flexion ( $P < .001$  for all) and knee rotation

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 ( $P < .001$ ).

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

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

260

## 261 Discussion

262 The main findings of the study were as follows: 1) FBCS did not reduce trunk angles  
263 during lateral movements, with even an increased trunk lateral lean during cutting maneuvers;  
264 2) hip internal rotation was increased with FBCS; 3) knee joint moments were not reduced with  
265 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

268 modality at the time of initial contact has already been provided in the literature.<sup>27</sup> But during  
269 perturbed lateral reactive jumps, trunk positioning was not influenced by the compression  
270 garment. It seems that despite a suit design enabling a reduced passive trunk range of motion,  
271 FBCS cannot support the trunk segment during an active dynamic movement. Thus, the trunk  
272 segment was not supported either during cutting maneuvers. On the contrary, trunk lateral lean  
273 was even significantly increased by 4° while wearing FBCS during 45° cutting maneuvers.  
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  
276 demonstrated that compression garments could reduce the active range of motion of the hip  
277 joint during a non-athletic task<sup>13</sup> and during sprinting,<sup>14</sup> a more neutral trunk positioning  
278 through apparel could not be achieved during unanticipated lateral movements. It might be  
279 possible that participants would rely on the support of the suit according to the compression  
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.

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

289 It appears that external passive support with the aim of enhancing trunk positioning  
290 during dynamic lateral movements classically encountered during team sports is difficult to  
291 achieve with apparel. At this point, further improvements to the design of the compression suit  
292 does not seem possible as several years of research and development were needed to yield this

293 current comfortable full-body suit, which enables reduced passive trunk flexibility through the  
294 combined compression and elasticity properties. In addition, garments were customized to each  
295 participant in the present study. Further increasing the compression level of the suit to further  
296 support body segments, i.e. by reaching typical values of compression socks  $> 15$  mmHg,<sup>30</sup>  
297 does not seem possible given that i) the straps used already increase the stiffness of the suit and  
298 ii) the higher compression level would reduce the comfort level necessary to perform whole-  
299 body dynamic movements.

300 Trunk and hip control alterations with FBCS could have consequences at the knee joint  
301 level. Indeed, higher trunk lateral lean during cutting maneuvers while wearing FBCS might be  
302 associated with increased knee joint loading.<sup>6,7</sup> In present study, higher trunk lateral lean had  
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  
305 angles with FBCS might reflect a lack of strength in the external hip rotators<sup>29</sup> and further a  
306 critical knee joint position (position of no return), where the hip moves more rapidly into  
307 adduction and internal rotation and the knee collapses in valgus.<sup>31</sup> But the consequences at the  
308 knee joint level during lateral reactive jumps were rather a reduction of the abduction and  
309 internal rotation angles whatever the landing condition with FBCS which speaks in favor of  
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.

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

318           It is worth noticing that FBCS had no influence on any of the performance parameters.  
319   The same level of agility while wearing the compression suit or in the control condition during  
320   the 5-10-5 yards test is consistent with the literature.<sup>13,16,32</sup> Although improvement of jumping  
321   performance with a compression garment has been reported in the literature,<sup>14,33</sup> it is interesting  
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  
328   sample size than 12 participants.<sup>34</sup> In the present study, measured variables were assessed over  
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.

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

343

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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 compression suit (FBCS) conditions.

Variable	Control (pooled LRJ)	FBCS (pooled LRJ)	<i>P</i> value	95% CI	ES ( $\eta^2_p$ )
Trunk Forward Lean ( $^\circ$ )	32.0 $\pm$ 6.2	31.6 $\pm$ 6.8	.66	[-1.7, 2.5]	.02
Trunk Lateral Lean ( $^\circ$ )	-7.5 $\pm$ 5.4	-7.9 $\pm$ 6.1	.63	[-1.4, 2.2]	.02
Trunk Right Axial Rotation ( $^\circ$ )	4.6 $\pm$ 9.4	6.7 $\pm$ 9.3	.10	[-4.7, 0.5]	.23
Hip Flexion ( $^\circ$ )	50.6 $\pm$ 8.9	51.1 $\pm$ 13.3	.84	[-5.5, 4.5]	< .01
Hip Abduction ( $^\circ$ )	35.5 $\pm$ 4.7	35.7 $\pm$ 5.7	.84	[-2.5, 2.0]	< .01
Hip Ext. Rotation ( $^\circ$ )	-5.0 $\pm$ 6.5	-11.1 $\pm$ 6.2*	.019	[1.2, 10.9]	.41
Knee Flexion ( $^\circ$ )	59.0 $\pm$ 5.3	59.9 $\pm$ 5.1	.10	[-2.0, 0.2]	.23
Knee Abduction ( $^\circ$ )	10.3 $\pm$ 6.7	5.3 $\pm$ 3.9**	.002	[2.3, 7.5]	.61
Knee Ext. Rotation ( $^\circ$ )	-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 body compression suit (FBCS) conditions.

Variable	Control	FBCS	<i>P</i> value	95% CI	ES ( $\eta^2_p$ )
Trunk Forward Lean (°)	12.6 $\pm$ 7.8	13.9 $\pm$ 5.6	.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 $\pm$ 7.5	.61	[-3.4, 2.1]	.02
Hip Flexion (°)	51.6 $\pm$ 6.7	49.3 $\pm$ 10.6	.35	[-2.9, 7.5]	.08
Hip Abduction (°)	8.4 $\pm$ 8.9	7.7 $\pm$ 5.9	.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 $\pm$ 5.0	28.0 $\pm$ 6.1	.56	[-0.9, 1.6]	.03
Knee Abduction (°)	4.7 $\pm$ 3.1	2.7 $\pm$ 3.1	.054	[-0.1, 4.1]	.30
Knee Ext. Rotation (°)	-7.4 $\pm$ 6.6	-3.4 $\pm$ 5.2	.052	[-8.1, 0.1]	.30
Knee Flexion Moment (Nm.kg <sup>-1</sup> )	0.16 $\pm$ 0.65	0.20 $\pm$ 0.75	.74	[-0.33, 0.24]	.01
Knee Abduction Moment (Nm.kg <sup>-1</sup> )	1.31 $\pm$ 0.46	1.20 $\pm$ 0.46	.30	[-0.12, 0.35]	.1
Knee Ext. Rotation Moment (Nm.kg <sup>-1</sup> )	-0.13 $\pm$ 0.11	-0.16 $\pm$ 0.12	.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.