

1 **The acute effect of maximal voluntary isometric contraction pull on**  
2 **start gate performance of snowboard and ski cross athletes**

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19 **ABSTRACT**

20 This study investigated whether adding a maximal voluntary isometric contraction  
21 (MVIC) to developing snowboard (SBX) and ski (SKIX) cross athletes' warm-up  
22 could reduce start time. A secondary aim was to assess the use of start performance  
23 as a talent identification tool for junior athletes by determining whether differences in  
24 time could be explained by participant age and anthropometry. Twenty sub-elite  
25 athletes (male:  $n = 11$ , female:  $n = 9$ , age:  $15.0 \pm 1.4$  years) participated. No  
26 differences were found for start time (7.5 m) between MVIC and standardised (no-  
27 MVIC) warm-up or gender (MVIC; males:  $1.36 \pm 0.07$  s, females:  $1.41 \pm 0.03$  s, no-  
28 MVIC; males:  $1.35 \pm 0.01$  s, females:  $1.38 \pm 0.10$  s,  $P > 0.05$ ). A strong relationship  
29 between body mass and start time to 7.5 m ( $r = -0.78$ ,  $r^2 = 0.61$ ,  $P < 0.05$ ) was  
30 observed. Use of MVIC-based warm-ups with developing SBX and SKIX athletes  
31 may not be beneficial to improving performance.

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33 **Keywords:** post-activation potentiation, snow sport, development, warm-up

## 34 INTRODUCTION

35 The snowboard (SBX) and ski (SKIX) cross events are relatively new Olympic winter  
36 sports, with SBX making an Olympic debut in 2006, and SKIX four years later in  
37 2010. For both sports, the ability of the participant to accelerate out of the drop down  
38 gates has been identified as an important factor in producing a high level of  
39 performance <sup>1-4</sup>. Specifically, moderate to strong correlations ( $r = 0.47-0.73$ ) have  
40 been noted between start time over the first 7.5 m of a course and an athlete's  
41 qualifying time in elite SKIX <sup>1, 2</sup>. Improving start performance can also provide an  
42 advantage over fellow competitors during the head-to-head racing phase, as getting  
43 out in front allows athletes to choose the most appropriate racing line whilst avoiding  
44 the need to overtake competitors <sup>1</sup>.

**Comment [SR1]:** Colloquial? Can you make this more scientific in your language?

45 Race performance of SBX and SKIX athletes has been found to be strongly  
46 associated with maximal push-off speed, bench press and pull strength, core power,  
47 and muscle pre-activation prior to start performance <sup>5, 6</sup>. Therefore, warm-up  
48 practices of SBX and SKIX athletes should physically prepare them for the explosive  
49 start essential to success in these events. Despite this, previous observational  
50 studies investigating competition practices of SBX and SKIX athletes have  
51 suggested that current warm-up practices may be less than ideal <sup>7</sup>. The negative  
52 effects of these practices may be further exacerbated when combined with the  
53 environmental constraints of sub-zero temperatures. Further, information relating to  
54 current warm-up practices and their effect on start performance is not available.  
55 Therefore it is important to determine whether improving current warm-up practices  
56 may offer an acute improvement in start time.

57 It is well established that the implementation of a maximal voluntary isometric (MVIC)  
58 pull exercise prior to exercise can exert acute performance effects on dynamic  
59 sporting movements, maximal force output and acceleration <sup>8-11</sup>. This predominantly  
60 occurs as a result of muscle post-activation potentiation (PAP), as MVIC's allow for  
61 the recruitment of higher order motor units, as well as myosin regulatory light chain  
62 phosphorylation <sup>12</sup>. Further, maximal isometric strength has been found to be related  
63 to elite performance measures in several sports such as cross country and Nordic  
64 combined skiing <sup>13</sup>, tennis <sup>14</sup>, and rowing <sup>15</sup>. Despite limited information available  
65 relating to the PAP response in developing athletes, the addition of an MVIC to

66 warm-up prior to competition could potentially improve time out of the start gates,  
67 thus improving overall race performance in SBX and SKIX competition<sup>6, 9, 10</sup>.

68 In developing athletes, certain anthropometric measures have also been found to  
69 have moderate to strong relationships with performance, particularly in sports such  
70 as alpine skiing<sup>16</sup>, soccer<sup>17</sup>, tennis<sup>18</sup>, American football<sup>17</sup>, and basketball<sup>19</sup>.  
71 Further, for athletes between the ages of 14 and 21 years, body mass and height  
72 have been shown to be higher in nationally selected snow sport athletes of the same  
73 competition age group<sup>16</sup>. Despite this, some studies have noted that chronological  
74 age exerts a minimal effect on performance measures within competition age groups  
75 less than 18 years<sup>17, 19</sup>. However, the influence of chronological age and  
76 anthropometric measures on start performance in developing SBX and SKIX athletes  
77 has yet to be established.

78 The aims of this study were to determine whether the addition of a MVIC pull  
79 exercise to the warm-up of developing SBX and SKIX athletes could improve start  
80 performance. This study also aimed to investigate the relationship between  
81 chronological age, height and body mass and start performance in this same sample  
82 population.

83

## 84 **METHODS**

### 85 **Participants**

86 Developing SBX and SKIX athletes (n = 20) were recruited from the Mount Buller  
87 Race Club, Victoria, Australia. Participant inclusion criteria were set for age (13-18  
88 years), level of involvement in the sport (at least 5 hours of training per week),  
89 familiarity with the start gate pull/push technique, no serious injuries in the last six  
90 months, and able to participate in two testing sessions 24 hours apart. The study  
91 protocol was approved by the relevant university human ethics advisory group and  
92 written consent was obtained from all participants/guardians.

93 Participants were informed about the purpose of the study and then completed a 15  
94 min warm-up familiarisation session prior to testing. During this session participants

95 received visual and verbal instructions in regards to the warm-up and expected start  
96 performance effort. Following this, participant standing height was measured prior to  
97 the first testing session using a stadiometer (Model 220, Seca, Hamburg, Germany),  
98 with body mass also recorded using electronic scales (Model UC-321, A&D  
99 Engineering Inc., San Jose, USA). Both measures were taken without shoes or snow  
100 clothing and measured to the nearest 0.1 cm and 0.1 kg.

### 101 **Warm-up Test Development**

102 The standardised (no-MVIC) warm-up protocol was adapted from the protocol  
103 presented by McMillian, et al. <sup>20</sup>. This consisted of a six minute general aerobic  
104 warm-up followed by body-weight squats, lunges, push-ups, leg swings (hip  
105 abduction/adduction/flexion/ extension), and arm swings (forward and backward  
106 rotation). Total time for both the no-MVIC and MVIC warm-up protocols was 27 min.  
107 The no-MVIC protocol included an 11 min rest following the general warm-up with  
108 the participant coached to remain stationary until instructed to prepare for the gate  
109 start. The MVIC pull warm-up was undertaken by each participant five minutes  
110 following completion of the standardised warm-up. This time interval was based on  
111 information received from SBX and SKIX coaches in that it most closely simulated  
112 competition scheduling procedures. The specific MVIC pull technique was based on  
113 the findings of Haff et al. <sup>21</sup> and Kawamori et al. <sup>22</sup> who found the isometric mid-thigh  
114 pull and isometric upper body conditioning exercises produces greater peak force  
115 (N) and peak power (W) output when compared to dynamic exercises. Participants  
116 placed a TRX Suspension Trainer (TRX Training, Leader Enterprises Inc., USA)  
117 under each foot with the handles adjusted to mid-thigh height once their knees and  
118 hips were bent slightly <sup>21-23</sup>. They were then instructed to pull upward on the TRX  
119 maximally for 3 x 3 s repetitions, with a three minute rest between repetition as  
120 outlined by French et al. <sup>9</sup> and Güllich and Schmidtbleicher <sup>10</sup>. The start gate  
121 performance was then undertaken within one minute of completing the MVIC pull <sup>9</sup>,  
122 <sup>10</sup>.

### 123 **Warm-up Testing**

124 The study comprised of a double cross-over design where participants were  
125 randomly assigned to either a standardised warm-up practice group (no-MVIC), or

126 the MVIC pull warm-up group (MVIC) on the first day (Day 1), and the subsequent  
 127 warm-up on the second day (Day 2). Participants acted as their own controls by  
 128 completing both warm-up sessions over one weekend, with a 24 hour wash-out  
 129 period between each session **as a minimum of 30 minutes is adequate for the**  
 130 **removal residual effects of PAP**<sup>9, 24</sup>. Testing sessions were conducted on two  
 131 separate weekends (four days), with each participant tested over one weekend only.  
 132 **All participants used the same boards/skis each session.** The on-snow testing was  
 133 performed at the Mt Buller Racing Club SBX and SKIX training area located on the  
 134 southern ski slopes of the Mt Buller Ski Resort, Australia. Hill slope was **measured at**  
 135 **the 5 m timing gate** recorded for each testing session to ensure that the slope angle  
 136 remained consistent between trials, with the range of the slope angle being 25-28°  
 137 across all four testing days. **Weather conditions and snow temperatures were**  
 138 **measured using a Kestrel 3000 Pocket Weather Metre (Nielsen-Kellerman,**  
 139 **Boothwyn, PA, USA) prior to each testing session. Temperature, humidity, wind**  
 140 **direction and speed, and snow temperature were all recorded to control for the**  
 141 **possible effects of environmental conditions on participants results.**

**Comment [SR2]:** There is evidence to contradict this but leave as is

## 142 **Start Time Data Collection**

143 Speedlight V2 (Swift Performance Equipment, Carole Park, Australia) timing gates  
 144 were used to collect split time ( $\pm 0.01$  s) data of participants as they exited the start  
 145 gate. Time was measured from the moment participants exited the gate, and then at  
 146 5.0 m, 7.5 m and 10.0 m. The effect of participant reaction time to a start signal was  
 147 accounted for, with the first timing gate placed directly next to the start gate handles  
 148 and time starting once the participant's torso crossed the beam.

## 149 **Statistical Analysis**

150 Descriptive statistics (mean  $\pm$  SD) were obtained for participant age, gender, body  
 151 mass and height. Cumulative times for 5.0 m, 7.5 m and 10.0 m for both the MVIC  
 152 and no-MVIC warm-up protocols were also obtained. Prior to the main analyses, a  
 153 Pearson's correlation coefficient matrix was generated in order to compare the  
 154 cumulative start times at 5.0 m and 10.0 m to the time at 7.5 m for both the MVIC  
 155 and no-MVIC warm-ups. Results showed that the 7.5 m time was strongly  
 156 associated with 10.0 m time for both MVIC ( $r = 0.92$ ,  $P < 0.01$ ) and no-MVIC ( $r =$

**Comment [SR3]:** As you have stated this here, you need to present the results somewhere. I say in the reply to reviewer document that it doesn't need to be a table, but it probably does after reading this – just make sure it is referred to in the Results section below.

157 0.97,  $P < 0.01$ ), with strong correlations also noted between 5.0 m and 7.5 m  
158 cumulative time for MVIC ( $r = 0.94$ ,  $P < 0.01$ ), and no-MVIC ( $r = 0.97$ ,  $P < 0.01$ ). As a  
159 result of these comparisons, subsequent analyses were undertaken using only the  
160 7.5 m as the dependent variable for start time. Also prior to undertaking main  
161 analyses, two exploratory analyses were conducted to determine whether  
162 differences for start time existed for 'Day' (Day 1 v Day 2) and 'Sport' (SBX v SKIX).  
163 A paired t-test was run for 'Day', with Mann-Whitney-tests conducted for 'Sport'.  
164 Neither comparison revealed any differences ( $P > 0.05$ ) for start time thus these  
165 groups were pooled for further analyses.

166 A two-way repeated-measures ANOVA was then conducted to determine the effects  
167 of a) the MVIC compared to no-MVIC warm-up protocols, and b) gender on start time  
168 to 7.5 m. To determine the strength of the relationships between start time and  
169 participant chronological age and anthropometric characteristics (body mass and  
170 height), separate correlation and a multiple linear regression analyses were  
171 undertaken. IBM SPSS Statistics version 22 (Version 22.0, IBM Corporation, USA)  
172 was used for all analyses, with statistical significance set at  $P < 0.05$  unless otherwise  
173 indicated.

174

## 175 **RESULTS**

176 Descriptive information relating to participants was as follows; age:  $14.90 \pm 1.40$   
177 years, height:  $1.72 \pm 0.09$  m, body mass:  $58.60 \pm 8.90$  kg. Descriptive statistics for  
178 start time by condition and participant characteristics are reported in Table 1, with  
179 start times ranging from 1.29 to 1.44 s for the MVIC warm-up and 1.25 to 1.48 s for  
180 no-MVIC warm-up. For the two-way repeated measures ANOVA, six participants  
181 failed to complete both days of testing, leaving a total of 14 for the main analysis.  
182 Reasons for this were due to participant injuries or illness prior to the second testing  
183 session. Results from the ANOVA revealed no significant differences (MVIC:  $1.39 \pm$   
184  $0.06$  s, no-MVIC:  $1.37 \pm 0.09$  s,  $P > 0.05$ ) between warm-up protocols when  
185 comparing start performance in isolation. The interaction effects between 'warm-up'  
186 (MVIC or no-MVIC) and 'gender' (male or female) were also not significantly different  
187 ( $P > 0.05$ ).

188

189

\*\*\*\*INSERT TABLE 1 ABOUT HERE\*\*\*\*

190

191 The results between MVIC start performance and participant anthropometric  
192 characteristics and age showed a strong relationship for body mass ( $r = -0.78$ ,  $P$   
193  $<0.05$ ), a moderate relationship ( $r = -0.53$ ,  $P <0.05$ ) for participant height, and a  
194 slightly lower relationship was noted for age ( $r = -0.39$ ,  $P <0.05$ ). The multiple  
195 regression for height, body mass and chronological age found these variables  
196 combined accounted for 65.2% ( $r^2 = 0.65$ ) of the variance in MVIC start performance.  
197 From this, only participant body mass was found to be a significant contributor ( $P$   
198  $<0.05$ ) to start time performance to 7.5 m. Therefore a second linear regression for  
199 body mass and MVIC start time to 7.5 m was consequently conducted, with a  
200 similarly strong relationship ( $r^2 = 0.61$ ,  $P <0.05$ ) between body mass and start time to  
201 7.5 m observed. This final parsimonious regression equation is shown in Figure 1.

202

203

\*\*\*\*INSERT FIGURE 1 ABOUT HERE\*\*\*\*

204

## 205 DISCUSSION

206 This study aimed to investigate whether the addition of an MVIC to an athlete's  
207 warm-up practice prior to competition could improve start time in SBX and SKIX.  
208 Despite previous evidence linking the use of MVIC to improved acute performance,  
209 results revealed no differences for start times for either MVIC or no-MVIC warm-up.

210 Descriptive characteristics of the participants such as age, body size, biological  
211 maturation, and training experience may in part explain the lack of differences  
212 observed in start performance<sup>25, 26</sup>. The mechanism behind the use of an MVIC's  
213 pre-start performance is that it may induce muscular PAP by allowing the recruitment  
214 of higher order motor units and phosphorylation of myosin regulatory light chain<sup>12</sup>.  
215 However, these participants may not have fully developed the musculature and  
216 corresponding strength and power for an MVIC to exert a PAP response that  
217 influenced start performance<sup>25, 27</sup>. Additionally, it has been shown that elite and



218 near-elite athletes across multiple sports (including skiing) specialise and increase  
219 sport-specific practice hours after the age of 18 years <sup>28</sup>. Therefore, it could be  
220 hypothesised that the participants included in this study did not possess the refined  
221 gross motor skills needed to utilise the PAP response from the MVIC warm-up and  
222 thus improve their start performance <sup>12, 26</sup>. Whilst the MVIC proved to exert no  
223 influence on start time in this developing athlete cohort, these findings need to be  
224 confirmed in older, elite SBX and SKIX athletic populations.

225 Gender was also not shown to exert a meaningful effect on start performance times  
226 for either MVIC or no-MVIC warm-up protocol. Previous work has shown that  
227 developing male alpine skiers perform better than their female counterparts in the  
228 Swiss cross run test for change of direction speed <sup>16</sup>. However, no on-snow  
229 physiological speed tests exist which would allow a similar comparison under the  
230 conditions experienced in this study. The findings in this study may also suggest that  
231 the SBX and SKIX start performance on-snow in this age group may be affected  
232 more so by the participants' age and body size rather than gender <sup>29, 30</sup>. The strong  
233 relationships noted in the linear regression analyses between body mass, height and  
234 start time support this hypothesis. The abovementioned study also showed that  
235 anthropometric measures (body mass and height) display moderate to strong  
236 relationships with performance in 14 to 21 year old alpine skiers <sup>16</sup>. These findings  
237 combined with those noted in this study have practical applications for the current  
238 age structure of competitions and talent identification of developing SBX and SKIX  
239 athletes, as smaller and lighter athletes may be at a disadvantage in regards to their  
240 start performance <sup>16</sup>. The higher body mass of these athletes results in greater  
241 momentum and ability to overcome resistance out of the start gate <sup>31</sup>. However,  
242 these inequalities in athlete size are transient and generally resolve with maturation  
243 <sup>32</sup>. Therefore, coaches and team selectors need to consider this if using start time as  
244 a measure for SBX and SKIX talent identification to ensure that talented, late  
245 developing athletes are not overlooked because of body size.

246 Whilst the MVIC proved to have no effect on start time to 7.5 m in this developing  
247 athlete cohort, this finding needs to be confirmed in elite SBX and SKIX athletic  
248 populations. It has been noted that athlete characteristics have an effect on the PAP-  
249 fatigue response to an MVIC conditioning contraction <sup>25</sup>. These include muscular

250 strength, muscle fibre type distribution, individual's training level, and type of  
 251 subsequent explosive activity <sup>12</sup>. It should also be noted that the use of a TRX device  
 252 to induce the MVIC may not have exerted the identical effect as that of a stationary  
 253 squat rack bar, which has been used previously for such purposes <sup>33</sup>. However,  
 254 environmental constraints would not allow for a squat rack to be used for on-snow  
 255 testing. Another possible contributor to the lack of MVIC effects could have related to  
 256 the attentional demands of the MVIC warm-up itself. Specifically, given the young  
 257 age of the participants the MVIC may have become the primary focus during testing,  
 258 which may have moved participant attentional focus away from the task itself <sup>34, 35</sup>.  
 259 Also, the relatively small sample size used in the study means further confirmation of  
 260 these results in larger, elite level sample populations is required.

261 The findings of this present study suggest the use of MVIC has no meaningful effect  
 262 on start performance in developing SBX and SKIX participants. Consequently, it can  
 263 be surmised that the use of such a protocol as part of the warm up in these sports  
 264 shows little value for this age group. The results also indicate that use of 7.5 m start  
 265 time is limited as a performance measure and talent identification tool **in isolation** for  
 266 adolescent athletes due to its strong relationship with body mass and height.  
 267 **However, start time may still be a viable tool for talent identification when modelled**  
 268 **with other race performance measures such as; time to first turn, course section**  
 269 **(turns and air) split times, and subjective athlete measures such as overtaking ability.**  
 270 This has practical applications for talent identification and age structured  
 271 competitions for developing SBX and SKIX athletes, as taller and heavier athletes  
 272 may have an advantage in regards to their start performance. **Future research**  
 273 **should assess the magnitude in-by which ~~body mass and height~~ the anthropometry of**  
 274 **junior SBX and SKIX influences all race performance measures to ensure equal**  
 275 **competition for all athletes, regardless of their maturity.**

**Comment [SR4]:** Do you have references for any of these measures? I think they are needed

276

## 277 CONCLUSION

278 The implementation of an MVIC prior to competition in developing SBX and SKIX  
 279 athletes does not appear to improve start time to 7.5 m. Factors such as age, body  
 280 size and biological maturation in developing athletes may diminish the potential for

281 PAP to enhance performance. Start time in SBX and SKIX is limited **in isolation** as a  
282 measure of performance in developing athletes, due to the positive influence of body  
283 mass and height on start time. This study has implications for **start performance time**  
284 **as a** talent identification **tool for** developing SBX and SKIX athletes as late  
285 developing athletes are disadvantaged **at the 7.5 m mark of the** **course**.

**Comment [SR5]:** I think this wording could be better...

286

## 287 **Acknowledgments**

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289 for a testing location to be organised for this study.

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**Comment [SR6]:** There seems to be two sets of references here?

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499



501 **Table 1.** Summary of results: MVIC versus no-MVIC (pooled genders and sports) warm-up protocol effects on start time (s) to 7.5  
 502 m. Presented as mean  $\pm$  SD.

Condition	Gender	Height (m)	Body Mass (kg)	Age (years)	Time to 7.5 m (s)
MVIC	Male	1.72 $\pm$ 0.11	60.06 $\pm$ 11.60	14.71 $\pm$ 1.60	1.36 $\pm$ 0.07
	Female	1.68 $\pm$ 0.08	55.50 $\pm$ 8.12	14.71 $\pm$ 1.38	1.41 $\pm$ 0.03
no-MVIC	Male	1.72 $\pm$ 0.11	60.06 $\pm$ 11.60	14.71 $\pm$ 1.60	1.35 $\pm$ 0.10
	Female	1.68 $\pm$ 0.08	55.50 $\pm$ 8.12	14.71 $\pm$ 1.38	1.38 $\pm$ 0.10

503

504 MVIC: maximum voluntary isometric contraction

505 **Figure Captions**

506 **Figure 1.** Start time (s) to 7.5 m based on participant's body mass (kg).

507