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

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

3

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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 ± 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 ± 0.07 s, females: 1.41 ± 0.03 s, no-
28 MVIC; males: 1.35 ± 0.01 s, females: 1.38 ± 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.

32

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 ¹⁻⁴. 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 ^{1, 2}. 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 ¹.

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 ^{5, 6}. 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 ⁷. 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 ⁸⁻¹¹. 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 ¹². 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 ¹³, tennis ¹⁴, and rowing ¹⁵. 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^{6, 9, 10}.

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 skiing¹⁶, soccer¹⁷, tennis¹⁸, American football¹⁷, and basketball¹⁹.
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 group¹⁶. 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^{17, 19}. 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. ²⁰. 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. ²¹ and Kawamori et al. ²² 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 ²¹⁻²³. 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. ⁹ and Güllich and Schmidtbleicher ¹⁰. The start gate
121 performance was then undertaken within one minute of completing the MVIC pull ⁹,
122 ¹⁰.

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**^{9, 24}. 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 (± 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 ± 1.40
177 years, height: 1.72 ± 0.09 m, body mass: 58.60 ± 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 ± 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^{25, 26}. 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 chain¹².
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^{25, 27}. 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 ²⁸. 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 ^{12, 26}. 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 ¹⁶. 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 ^{29, 30}. 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 ¹⁶. 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 ¹⁶. The higher body mass of these athletes results in greater
241 momentum and ability to overcome resistance out of the start gate ³¹. However,
242 these inequalities in athlete size are transient and generally resolve with maturation
243 ³². 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 ²⁵. These include muscular

250 strength, muscle fibre type distribution, individual's training level, and type of
 251 subsequent explosive activity ¹². 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 ³³. 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 ^{34, 35}.
 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**

288 The authors would like to thank the Mount Buller Race Club and Coaches that allowed
289 for a testing location to be organised for this study.

290 **References**

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