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Field-based and overspeed potentiated warm-ups increase clubhead speed and drive carry distance in skilled collegiate golfers

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Bliss, Alex; Livingstone, Harrison; Tallent, Jamie

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23 **Abstract:**

24 Warm-ups utilising post-activation performance enhancement (PAPE) strategies have been
25 shown to increase clubhead speed (CHS) in golfers. However, the effectiveness of overspeed
26 training using weighted clubs to elicit PAPE in CHS is unknown. The purpose of this
27 investigation was to compare traditional, field-based warm-up activities with no potentiation
28 activity (CON), against a field-based potentiated warm-up using high rate of force development
29 bodyweight movements (BWP), and an overspeed warm-up using speed sticks (SSP) as the
30 potentiation method. Thirteen skilled adult male golfers (handicap 1.0 ± 2.1) completed three
31 testing sessions, separated by seven days. The CON, BWP and SSP warm-ups were
32 identical, except for the potentiation method. After each warm-up condition, ten shots,
33 separated by one minute, were recorded using a doppler rader launch monitor (Trackman 4)
34 with CHS, ball speed (BS), carry distance (CD) and total distance (TD) recorded. A repeated
35 measures one-way ANOVA with Bonferroni *post hoc* pairwise comparisons revealed
36 increases in CHS in the BWP ($p= 0.004$) and SSP ($p= 0.003$) groups against CON, with no
37 difference between BWP and SSP. Increased CD was observed for BWP ($p= 0.034$) and SWP
38 ($p= 0.030$) against CON with no differences between BWP and SSP. No differences for BS or
39 TD were observed. Warm-ups with BWP or SSP activities should be considered if players are
40 attempting to increase CHS or CD of drives, although utilising overspeed potentiation methods
41 appear to confer no additional benefit to bodyweight PAPE exercises in skilled collegiate
42 golfers.

43 **Keywords:** golf, warm-ups, overspeed, speed sticks, post activation potentiation effect

44 **Introduction:**

45 Effective warm-ups for athletic performance typically follow the sequential “Raise, Activate,
46 Mobilise, Potentiate” (RAMP) model originally proposed by Jeffreys¹ where body
47 temperature and heart rate are raised, muscles are activated and joints mobilised, before the
48 musculature is primed or potentiated for the task about to be performed in a sequential

49 manner. Golf warm-ups that contain these elements have been shown to improve
50 determinants of drive performance in golf including clubhead speed (CHS), driving distance
51 and strike quality². Conversely, warm-ups that focus on static stretching and do not adhere to
52 the RAMP model have been demonstrated to contribute to decrements in these performance
53 measures.³ A recent review of warm-ups in golf has provided a thorough overview of the area,
54 suggesting that to be practically viable, warm-ups should include some form of resistance
55 exercise but with minimal equipment.⁴ However, none of the studies systematically
56 investigated contained golf-specific overspeed potentiation methods, or directly compared
57 bodyweight resistance exercises and golf swing specific potentiation methods. The work of
58 Tilley and McFarlane⁵ did use a weighted club, but this was used at the start of the warm-up.
59 Overspeed potentiation methods have been shown to confer increases in swing speed in
60 sports with a similar rotational striking movements such as baseball.^{6,7} However, there is
61 currently no evidence on overspeed potentiation methods in golf as an acute strategy to
62 enhance CHS. Therefore, understanding whether warm-ups containing an overspeed
63 potentiation strategy deliver maximal performance improvements is necessary.

64 Research in this area is useful as it may offer simple methods by which to increase CHS, and
65 subsequently drive distance. Although drive distance is underpinned by a myriad of factors,
66 the principal component for increased drive distance is increased CHS.⁸ For example, CHS
67 is strongly correlated with handicap index in amateur golfers, with better players demonstrating
68 a strong correlation with CHS.⁹ At the elite level, long-hitting golfers are more likely to score
69 better on par four and five holes on the PGA tour.¹⁰

70 Post activation potentiation (PAP) is a commonly used technique by strength & conditioning
71 practitioners to acutely improve physical qualities of athletes that are required to perform
72 forceful muscular contractions.¹¹ Traditionally, PAP is observed by evoking a muscle twitch
73 using electrical stimulation after an intense voluntary contraction, although it has also recently
74 been defined as a voluntary force or power enhancement after a high-intensity warm-up.¹²
75 This linked, but separate phenomenon is termed the post-activation performance

76 enhancement (PAPE) effect and is thought to result from increases in muscle temperature,
77 muscle and muscle fibre water content, and other central and peripheral mechanisms to
78 improve muscle activation.¹² Previous studies in golf have shown that PAPE activities can elicit
79 positive and transferable effects to golf driving performance and CHS. Research conducted
80 by Read, Miller & Turner has shown that skilled golfers increased CHS by 2.25 miles per hour
81 (mph) after completing a series of bodyweight countermovement jumps (CMJ).¹³ However,
82 golfers may be reluctant to perform this type of warm-up because it is not common amongst
83 their peers or (because it is a generic athletic movement rather than a golf movement) they
84 may not know how to.⁴ Conversely, a study of skilled golfers undergoing professional training
85 demonstrated that warm-ups are perceived to be beneficial for golf performance, and that over
86 50% of players undertake air swings with a golf club as part of their preparations.¹⁴
87 Furthermore, studies investigating changes to CHS in golf following weighted club warm-ups
88 are lacking. Based on the research of Ehlert & Wilson⁴, this type of warm-up may be more
89 attractive as it mimics the golf swing, but it does involve specialist equipment.

90 Enhancements in muscular force production from PAPE activities have been observed
91 following dynamic, high-speed activities.¹² Studies from sports with similar rotational
92 hitting/striking profiles to golf such as baseball have found that performing maximal effort
93 swings as part of a warm-up with lighter than normal, or normally weighted bats can increase
94 subsequent normal bat swing velocity by approximately 4%, but heavier bats confer no
95 benefit.⁶ Therefore, it was the purpose of this study to compare the effects of both high-rate of
96 force development bodyweight PAPE exercise (BWP) or an overspeed warm-up using speed
97 sticks (SSP) on golf drive performance.

98 **Methods**

99 ***Participants***

100 Thirteen skilled adult male golfers (age= 20 ± 1 yrs; height= 1.82 ± 0.08 m; body mass= 77.55
101 ± 7.11 kg; handicap= 1.0 ± 2.1) were recruited to the study. To be included in the study,

102 participants must have been a category one handicap (5.4 or lower) or professional. Twelve
103 participants were amateur and one was professional, who was given a handicap of zero for
104 the purposes of the study. Participants were recruited from a research advert which was
105 placed at a golf college in the United Kingdom (UK) and golf clubs local to the university. All
106 participants were free from injury. Power analysis was carried out using G*Power (v3.1.9.7) *a*
107 *priori*, determining that with an estimated effect size of 0.6 (based on the similar work of
108 Coughlan et al.¹⁵) and an alpha level of 0.05. 12 participants were required to achieve a power
109 >80%. The study was conducted in accordance with the principles of the Declaration of
110 Helsinki (2013) and ethical approval was granted by the institution's ethics committee.

111 ***Procedure and measurements:***

112 Participants attended all testing sessions at the same time of day, separated by one-week.
113 Participants were instructed to avoid strenuous activity 24-h prior to assessment and to arrive
114 in a rested condition. Participants were asked to avoid eating or drinking anything other than
115 water at least 2-h prior to assessment, and to avoid consumption of any nutritional
116 supplements on the day of assessment. For the golf assessment, all testing sessions were
117 carried out in an outdoor, covered driving range in the UK in similar weather conditions. A
118 computerised launch monitor (Trackman 4, Trackman Golf, Denmark) was used to collect shot
119 data. Participants used their own drivers, although the same balls (Srixon Range Balls, Srixon
120 Sports Europe, UK) were used for each participant. The launch monitor was calibrated and
121 set to a "normalised" setting for all testing sessions to account for variables such as wind
122 direction, ground conditions, ball quality etc. Data fields recorded were: CHS, ball speed (BS),
123 carry distance (CD) and total distance (TD). Previous research has demonstrated that the
124 Trackman 3e (the previous model to the 4) has a median accuracy of 0.18m/s and 0.09m/s
125 for CHS and BS respectively.¹⁶ The Trackman 4 is a newer model than the 3e and is expected
126 to be as accurate, if not more accurate than its predecessor.¹⁷ If an error occurred and the
127 launch monitor did not record all of these fields the participant was asked to re-hit.

128 Participants undertook three separate protocols. Each was categorised by the type of warm-
129 up. Each warm-up was identical in nature, except for the final activities which aimed to elicit a
130 PAPE effect. Protocol one (CON) consisted of players completing the standardised warm-up
131 (Table 1) with no potentiating activity and acted as a control. Protocol two added high rate of
132 force development bodyweight plyometric exercises as a potentiating activity to the standard
133 warm-up (BWP). Protocol three added overspeed training using Speed Sticks (SuperSpeed
134 Golf, Tulsa, OK, USA) to the CON protocol to act as the potentiating activity (SSP)). The Speed
135 Sticks were light (20% lighter than a standard men's driver), medium (10% lighter) and heavy
136 (around standard driver weight or up to 5% heavier). After completion of the warm-up,
137 participants would rest for one minute before hitting 10 maximum effort drives with a 60 second
138 rest between shots in accordance with previous research.¹⁸ Participants were asked to "swing
139 as hard as possible, but with a technique that you would use when playing a real course".

140 *Statistical Analysis:*

141 A statistical package (IBM SPSS Statistics, v24.0, IBM Corporation, USA) was utilised for data
142 analysis. Descriptive statistics are presented as mean \pm standard deviation. The score for
143 each dependent variable was taken as the mean value of all shots performed per condition
144 after any outliers were removed in accordance with previous research.¹⁸ The outlier analysis
145 employed box-and-whisker plots to remove any mishit shots. Values outside of 1.5* the lower
146 bound for each dependent variable were removed. A one-way repeated measures analysis of
147 variance (ANOVA) with partial eta squared (η_p^2) effect size calculations was conducted to
148 compare means of the three groups for each dependent variable. Data were checked for
149 sphericity using Mauchly's test, with any violations adjusted using the Greenhouse-Geiser
150 correction. Effect sizes were classified as ≥ 0.1 = small; ≥ 0.3 = medium; ≥ 0.5 = large.¹⁸ Where
151 significant effects were observed, Bonferroni *post hoc* comparisons were used. An alpha level
152 of ≤ 0.05 was used for significance.

153 **Results:**

154 From 390 shots performed, the outlier removal process disregarded 24 shots. All participants
155 had at least seven data points for each dependent variable for each protocol following outlier
156 removal. Descriptive data are displayed in Table 2. ANOVA revealed significant, large effects
157 of warm-up on CHS ($F_{(2,24)} = 14.822$. $p = <0.001$. $\eta_p^2 = 0.553$) and significant medium effects
158 on CD ($F_{(2,24)} = 5.569$. $p = 0.01$. $\eta_p^2 = 0.317$). Bonferroni *post hoc* comparisons revealed, when
159 compared to the CON condition, increased CHS in the BWP (110.1 ± 5.5 vs 111.6 ± 5.1 mph.
160 $p = 0.004$. $ES = 0.28$) and SSP conditions (110.1 ± 5.5 mph vs 111.6 ± 5.2 . $p = 0.003$. $ES =$
161 0.28), but no difference between BWP and SSP ($p = 1.000$). Compared to the CON protocol,
162 increased CD was observed for the BWP (261.5 ± 16.4 yards vs 267.1 ± 14.2 . $p = 0.034$. $ES =$
163 0.37) and SSP conditions (261.5 ± 16.4 vs 268.2 ± 16.0 yards. $p = 0.030$. $ES = 0.41$), but no
164 difference between BWP and SSP ($p = 1.000$). No other significant effects were found for BS
165 or TD (all $p > 0.05$). The dependent variables with significant effects are displayed in Figure 1.

166 **Discussion:**

167 The aim of this study was to investigate three identical warm-up protocols that varied in
168 potentiation method only and their effects on golf driving performance in skilled adult golfers.
169 The novel element of this study is the use of overspeed training utilising weighted clubs as a
170 potentiation method in a warm-up. The study found that utilising BWP or SSP methods can
171 acutely increase CHS and CD in skilled golfers, but do not influence BS or TD.

172 Undertaking a warm-up prior to golf performance, despite recent evidence, appears to be a
173 behaviour that is perceived as important by skilled professional golfers¹⁴ but is not well
174 established in amateur golfers.⁴ This is surprising given that much recent research has
175 demonstrated the positive benefits of doing so.^{2,5,15} A key finding from this study is that
176 undertaking maximal effort activity using BWP or SSP to finish the warm-up appears to cause
177 a PAPE effect and creates increases in CHS and CD when compared to a warm-up with no
178 potentiation activity. However, it also appears that there are no differences between the
179 increase if the potentiating activity is generic (BWP) or sport-specific (SSP). This finding is
180 similar to that of Langdown et al.² who reported that even though both conditions were greater

181 than the control group, there were no differences in any of the five drive metrics (BS, launch
182 angle, total spin, dispersion, CD) monitored between their dynamic warm-up and resistance
183 band-warm-up, with the exception of launch angle which showed a larger reduction in the
184 dynamic group. Interestingly, while Langdown et al.² did not measure CHS (they report an
185 increase in BS), they showed no difference in CD, but increases were found in this study. This
186 may be explained by impact conditions (spin rates, launch angles etc.) or by the high-intensity,
187 maximal effort potentiation activities utilised in this study in comparison to the multiple
188 repetition or duration-based dynamic and banded activities undertaken in the work of
189 Langdown et al.² To substantiate this contention, Read et al.¹³ reported an increase in CHS
190 when using CMJs to potentiate, with their increase (2.2% equating to 2.25 mph) greater than
191 that reported here (1.4% equating to 1.50 mph) in the BWP group. While both increases were
192 significant, the participants in this study had higher CHS (110.1 ± 5.5 mph in the CON no
193 potentiation condition) than those in the Read study (106.9 ± 6.6 mph).¹³ It may be that as the
194 participant's "normal" CHS increases, that the effect size of a BWP warm-up becomes smaller.
195 Future research could address this by comparing warm-ups designed to elicit a PAPE effect
196 in high and low CHS participants.

197 Overspeed training is a practice that has garnered attention in other rotational striking sports
198 such as baseball,^{6,7} but has seen a recent revival in golf, through the use of weighted golf
199 clubs. However, despite these implements being widely used across all levels of golf including
200 the elite level, there is currently no peer-reviewed evidence to support their use. In baseball,
201 warm-ups utilising maximal effort swings with lightweight or normally weighted bats elicited
202 improvements (8.3% and 4.8% increases, respectively) in bat swing speed against using
203 heavily weighted bats.⁶ In a separate warm-up study utilising a range of weighted baseball
204 bats from very light to very heavy as potentiation methods, bats within 10% of the weight of a
205 normal bat produced the greatest swing speeds.⁷

206 A limitation of this study is that, even though the participants were accustomed to regular
207 physical activity and we would not expect an order effect, the warm-up conditions were not

208 randomised. Additionally, assessment of muscular recruitment pattern or activity (via
209 electromyography) or force production (via force platform) was not conducted. Therefore, the
210 mechanism by which the improvements in CHS and CD can only be speculatively attributed
211 to a PAPE effect. Future research should investigate how kinetic and kinematic factors that
212 underpin CHS or CD are enhanced as a result of a RAMP warm-up.

213 Although CHS and CD were enhanced in both BWP and SSP conditions, no other dependent
214 variables demonstrated an improvement. This finding likely demonstrates that increases in
215 CHS, while a major determinant of drive distance, is not the only factor that underpins drive
216 performance. Launch angles (vertical and horizontal), spin rates, and centredness of strike on
217 the clubface are also key factors that underpin early ball flight characteristics and ultimately
218 TD.²⁰ Furthermore, Parker, Hellstrom, and Ollson²¹ demonstrated that individual swing
219 techniques are a crucial aspect of CHS in males and females of comparable handicap and
220 age to those in this study, although CD was less influenced by individual variance in technique.
221 It was also suggested by that the factors that underpin CHS and CD are not transferable in
222 males and females.²¹ In this regard, kinetic and kinematic variables relating to individual swing
223 technique were not collected during the testing protocols and are limitations of this study.
224 Further, it was conducted in a male only cohort and as such the findings should not be
225 considered generalisable to female golfers. Future research should investigate whether there
226 are kinetic and kinematic alterations to swing technique as a result of BWP or SSP activities
227 in addition to monitoring drive performance.

228 Lastly, it is acknowledged that there were large interindividual differences in response to the
229 BWP and SSP warm-up conditions. As an extreme example, one participant experienced a
230 20 yard increase in CD in the SSP condition vs CON, as where another saw a decrease of 9
231 yards when using a SSP warm-up versus no potentiating activity. This variation in response
232 to warm-ups aiming to elicit a PAPE effect has been previously reported. These findings are
233 similar to those of Langdown et al² who stated, that even though all participants in their study
234 (and this study) were category 1, skilled players, there was considerable variability in response

235 to warm-up conditions. Additionally, a study by Till & Cooke²² showed a variance of 15.3%
236 between individual responses to PAP activities on sprint and jump performance in academy
237 footballers. The authors stated that athletes with greater muscular strength and high training
238 exposure had greater individual responses to PAP interventions.²² Furthermore, athletes with
239 greater training experience have greater responses to PAP due to physiological make up of
240 muscle fibres and motor units.²³ Athletes with limited or no training experience have reduced
241 responses to potentiating activity²³ and lack of training experience or fitness levels is also
242 shown to inhibit potentiating effects.²⁴ Therefore, it is likely that the participant's strength
243 characteristics will influence how they respond to RAMP based warm-ups and golfers with
244 greater physical training experience may experience the most benefit. Limitations of this study
245 were that strength characteristics of the participants were not measured and internal load was
246 not monitored and therefore whether the individual responses to the BWP and SSP warm-up
247 conditions could be attributed to strength levels is unknown. Future research in this area
248 should collect field or laboratory measures of the participants' force generating capabilities or
249 internal load (through heart rate or rating of perceived exertion as examples) to provide useful
250 information that may support or help to explain the variations in drive performance between
251 participants.

252 **Conclusions:**

253 A warm-up that follows the RAMP protocol and contains either BWP or SSP activities elicit
254 improvements in CHS and CD in skilled amateur male golfers. However, there were no
255 differences between using BWP or SSP and therefore the type of potentiation activity at the
256 end of a warm-up appears to be comparable. It is important that potentiation activities are
257 performed at maximum effort. However, BWP and SSP warm-ups did not improve BS or TD
258 and therefore the other kinetic and kinematic determinants of drive performance such as
259 centredness of strike, launch angle, and spin rate need to be maintained when attempting to
260 increase CHS and CD. Golfers can acutely increase CHS or CD through a physical warm-up
261 if they perform BWP or SSP activities. This increase could support training or competition play

262 and may help golfers improve their drive performance on the opening hole, which will acutely
263 improve players' scoring potential. However, it is unknown how long these performance
264 benefits will last and future research which studies the effects of a BWP or SSP warm- up over
265 a longer playing duration than the opening drive is warranted.

266 **Conflict of Interest:**

267 The authors declare no conflict of interest

268 **Acknowledgements:**

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270 participants for providing their time and efforts undertaking the study.

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339 Table 1: Standardised sequential RAMP-based warm-up protocol

Raise

Skipping (2 minutes)

Activation and mobilisation

Leg swings x 10 ES

Resistance band shoulder external rotations 10 ES x 2

Single leg kneeling kickbacks x 10 ES

Lunges with rotations x 10 ES

Overhead squats with golf club x 12

Golf Swing Specific

Sand wedge pitch shots x 3

Sand wedge full shots x 3

7 iron full shots x 2

Driver full shots x 2

Potentiation

Condition		
CON	BWP	SSP
None	CMJ 10 reps x 3	SSS Light Dominant Side x 10
	Plyometric Press Ups 10 reps x 2	SSS Light Non-Dominant Side x 10
		SSS Medium Dominant Side x 10
		SSS Heavy Dominant Side x 10

340 ES = Each side. CMJ= Countermovement Jump. SSS= Super Speed Stick. Reps =
 341 repetitions

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349 *Table 2: Mean (\pm SD) values for drive variables across warm-up conditions*

	CON	BWP	SSP
CHS (mph)	110.1 \pm 5.5	111.6 \pm 5.1*	111.6 \pm 5.2*
BS (mph)	160.5 \pm 8.0	161.8 \pm 7.2	161.9 \pm 7.9
CD (yards)	261.5 \pm 16.4	267.1 \pm 14.3*	268.2 \pm 16.0*
TD (yards)	285.1 \pm 17.8	287.7 \pm 15.7	289.2 \pm 18.0

350 *= statistically significant ($p \leq 0.05$) increase vs CON condition

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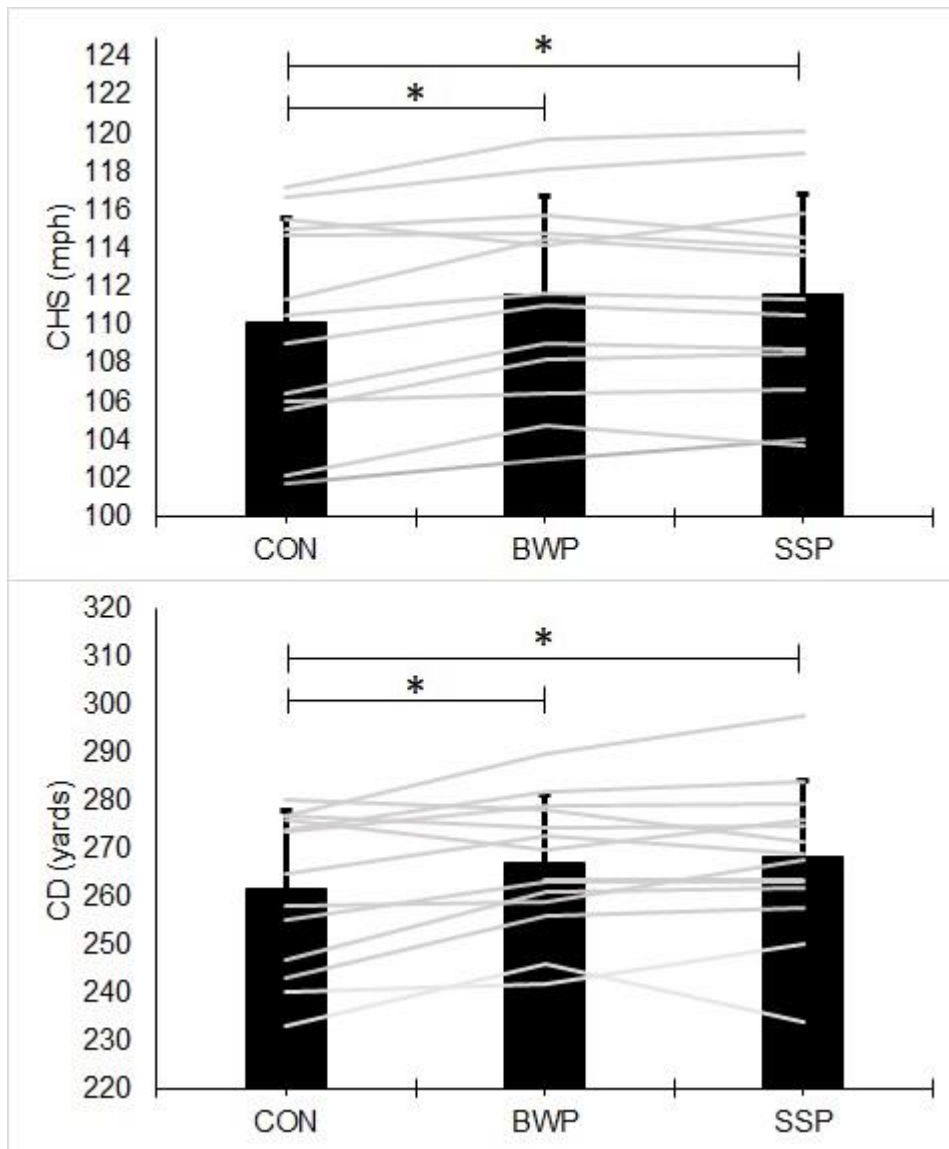
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368 **Figure 1:** Mean CHS (top) and CD (bottom) for all warm-up conditions. Error bars represent
 369 SD. Grey lines represent individual responses. *= significant difference ($p < 0.05$)

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