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27 Abstract

28 **Background:** Compared with visual torque-onset-detection (TOD), threshold-based TOD
29 produce onset bias, which increases with lower torques or rates of torque development (RTD).

30 **Purpose:** To compare the effects of differential TOD-bias on common contractile parameters in
31 two torque-disparate groups. **Methods:** Fifteen boys and 12 men performed maximal, explosive,

32 isometric knee-extensions. Torque and EMG were recorded for each contraction. Best
33 contractions were selected by peak torque (MVC) and peak RTD. Visual-TOD-based torque-time

34 traces, electromechanical delays (EMD), and times to peak RTD (tRTD) were compared with
35 corresponding data derived from fixed 4-Nm- and relative 5%MVC-thresholds. **Results:** The

36 5%MVC TOD-biases were similar for boys and men, but the corresponding 4-Nm-based biases
37 were markedly different (40.3 ± 14.1 vs. 18.4 ± 7.1 ms, respectively; $p < 0.001$). Boys–men EMD

38 differences were most affected, increasing from 5.0 ms (visual) to 26.9 ms (4 Nm; $p < 0.01$). Men's
39 visually-based torque kinetics tended to be faster than the boys' (NS), but the 4-Nm-based

40 kinetics erroneously depicted the boys as being much faster to any given %MVC ($p < 0.001$).

41 **Conclusions:** When comparing contractile properties of dissimilar groups, *e.g.*, children *vs.*
42 adults, threshold-based TOD methods can misrepresent reality and lead to erroneous conclusions.

43 Relative-thresholds (*e.g.*, 5% MVC) still introduce error, but group-comparisons are not
44 confounded.

45 **Key words:** EMD; RTD; RFD; Torque kinetics; Onset bias; Children

46 **Abbreviations**

47 ANOVA – Analysis of variance

48 EMG – Electromyography

49 EMD – Electro-mechanical delay

50 HSD – Honest significant difference

51 MVC – Maximal voluntary contraction

52 RFD – Rate of force development

53 RTD – Rate of torque development

54 RTD_{pk} – Peak rate of torque development

55 TOD – Torque-onset determination

56 Tq – Torque

57 tRTD – Time to peak rate of torque development

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64 **Conflict of Interest**

65 There are no conflicts of interest to report

66 **Introduction**

67 The capacity to rapidly generate force, or torque (Tq), is widely recognized as vital to
68 important aspects of physical performance and health (de Ruyter *et al.* 2006; Domire *et al.* 2011;
69 Krosshaug *et al.* 2007; Tillin *et al.* 2010; Tillin *et al.* 2013a). In studying rapid force or Tq
70 generation, detecting the onset is central to the quantification of the timing, coordination, and
71 kinetics of muscular contractions.

72 Visual ('manual') inspection of Tq traces is widely regarded to as the 'Gold Standard' of Tq-
73 onset detection (TOD; *e.g.*, (Tillin *et al.* 2010)). Although subjectivity (*e.g.*, (Staude and Wolf
74 1999) and lower reliability (Thompson *et al.* 2012) have been pointed out as possible drawbacks
75 of visual TOD, the magnitude of the associated errors is typically very small. Tillin *et al.* (Tillin *et al.*
76 *et al.* 2013b) reported both intra- and inter-observer visual TOD variability of less than 2 ms. Thus,
77 the chief drawback of visual TOD is the high time investment required when large numbers of
78 contractions must be analysed.

79 Consequently, automated, computer-based methods have been introduced to expedite
80 TOD. The most ubiquitous has been the threshold approach, designed to overcome signal/baseline
81 noise. Most methods use a threshold Tq level just high enough to clear the highest noise level in
82 the trace's baseline. Typically, such thresholds are defined as a certain absolute Tq value (*e.g.*,
83 (Asai and Aoki 1996)), a set number of standard deviations of baseline noise (*e.g.*, (de Ruyter *et al.*
84 *et al.* 2004; de Ruyter *et al.* 2006)), or a percentage of peak Tq (Tq_{pk}) (*e.g.*, (Aagaard *et al.* 2002;
85 Andersen and Aagaard 2006)). Tq onset is then determined as the first Tq data point to emerge
86 above that threshold (Figure 1). However, while fast and unquestionably-objective, such methods
87 are subject to considerable systematic bias. Threshold-determined onsets always occur later than
88 the actual ones (Figure 1) and the resulting biases typically range from ~20 ms (Pain 2003) to as

89 much as ~330 ms (Soda *et al.* 2010). Even the smaller biases can have far-reaching consequences
90 for interpreting the initial stages of Tq development (de Ruyter *et al.* 2006; Domire *et al.* 2011;
91 Krosshaug *et al.* 2007; Tillin *et al.* 2010; Tillin *et al.* 2013a). Most obvious would be systematic
92 lengthening of the derived electro-mechanical delay (EMD) and shortening of Tq kinetics
93 parameters such as the times to peak rate of Tq development (tRTD), or to any level of attained
94 Tq (*e.g.*, to 30%MVC). For a general review of threshold-methods' effects on TOD, see the recent
95 review by Maffiuletti *et al.* (Maffiuletti *et al.* 2016)

96 [**Figure 1**]

97 Onset bias increases with increasing baseline noise due to the necessarily higher thresholds.
98 Biases further increase with lower rates of Tq development (RTD) such as in slower *vs.* faster
99 contractions. In test-retest situations, or when comparing groups of similar contractile
100 characteristics, such biases are relatively constant and the effect on a study's construct validity
101 may be acceptably small. However, when dissimilar conditions or groups are compared, the onset
102 bias may have profound effects. A salient example of this is child–adult comparisons, which have
103 been receiving increasing attention (Cohen *et al.* 2010; Dotan *et al.* 2013a; Dotan *et al.* 2013b).
104 Children produce much lower absolute torques than adults and substantial differences persist even
105 when size-normalized torques are compared. Moreover, children's peak RTD (RTD_{pk}) values,
106 both absolute and Tq-normalized, are also typically lower and their Tq kinetics slower (Cohen *et*
107 *al.* 2010; Dotan *et al.* 2013a; Dotan *et al.* 2013b; Mitchell *et al.* 2011).

108 Thus, the purpose of the present study was to quantify and compare the effects of different
109 typical TOD methods on boys–men comparisons of commonly derived parameters of explosive
110 muscular contraction. We hypothesized that children's lower maximal torque will result in greater

111 onset bias compared with men, particularly when using a fixed-threshold TOD. This larger bias
112 will result in apparent faster initial torque kinetics.
113

114 **Methods**

115 **Participants**

116 Fifteen prepubertal boys (Pubertal maturity stage 1; Tanner 1962) and 12 adult men were
117 recruited for the study. All were healthy with no known conditions that could affect their
118 performance in any way. Their physical characteristics are summarized in Table 1. The
119 participants were all informed of the study's procedures and risks, and they, or their parents,
120 signed an informed consent form in compliance with the study's approval by the institutional
121 Research Ethics Board.

122 [**Table 1**]

123 **Study's Design**

124 Each participant performed maximal, explosive, isometric knee-extensions with Tq and
125 electromyographic (EMG) signals simultaneously recorded for each contraction. Data acquisition
126 and analysis are detailed below. In short, EMG onset, visually-determined Tq onset, RTD_{pk}, and
127 Tq_{pk} (MVC) were determined. A representative Tq trace was derived for each participant and
128 EMD and tRTD were calculated. Threshold-derived Tq-onset biases were determined for the 4
129 Nm and 5% MVC levels and threshold-specific EMD and tRTD values calculated.

130 The 4 Nm-threshold was chosen to represent typical thresholds used to clear baseline noise.

131 Thresholds have been set as high as 7.5 Nm in other studies (e.g., Andersen & Aagaard 2006) and
132 thus our 4-Nm threshold is a conservative one. The 5% MVC-threshold was used to correct
133 (normalize) for the large group differences in Tq_{pk}. We are aware that thresholds are often defined

134 as n standard deviations of baseline noise. This, however, translates to a fixed threshold unless the
135 dynamometer or testing conditions are different for the compared groups. This was not the case in
136 the present study.

137 The 5% MVC mean closely approximates the boys' 4-Nm threshold, but is much higher than
138 that in the men, thus making method comparisons more directly evident.

139 **Torque Measurement**

140 Tq testing was performed on a Biodex System III isokinetic dynamometer (Biodex, Shirley,
141 NY) with the participant's dominant leg (determined as the preferred leg to kick a ball). The
142 participants were seated on the dynamometer's chair with 80° hip flexion and 90° knee flexion
143 (where 0° is full extension in both joints). The participant was stabilised using Velcro straps
144 across the torso and pelvis and the shank was secured to the dynamometer's lever arm using
145 inextensible, unpadded Velcro straps three centimetres superior to the most proximal point of the
146 lateral malleolus. The axis of rotation of the lever was aligned with the lateral epicondyle during
147 contraction.

148 At least three submaximal and two maximal (MVC) explosive isometric contractions were
149 part of the warm-up and habituation that preceded testing. Participants performed eight 3-s
150 isometric MVCs separated by at least 30 s. They were instructed to perform each contraction as
151 fast and as hard as possible. To maximise motivation, verbal encouragement and visual feedback
152 from the dynamometer's monitor were provided throughout all trials. The Biodex scaling function
153 was used to maximize the signal-to-Tq ratio (*i.e.*, the function changes the ratio so that both men's
154 and boys' disparate torques effect similar, highest possible voltage response).

155 **EMG Recording**

156 EMG signals were recorded from the vastus lateralis and biceps femoris muscles using
157 Delsys 2.1 bipolar surface electrodes (Delsys Inc., Boston, MA, USA) following standard
158 (Hermens *et al.* 1999) skin preparation. A reference electrode was placed on the spinous process
159 of the 7th cervical vertebra.

160 **EMG and Torque Data Acquisition and Analysis**

161 The EMG and Tq signals were captured synchronously by a 16-bit A/D converter (BNC-
162 2110, National Instruments) and recorded in the EMGworks Data Acquisition System (Delsys
163 Inc., Boston, MA, USA). EMG signals were sampled at 1000Hz and band-passed filtered (20–
164 450Hz) using the Bagnoli-4 bioamplifier (Delsys Inc., Boston, MA, USA). Tq signals from the
165 Biodex were also sampled at 1000Hz with at least 1s of resting baseline data recorded prior to any
166 given contraction. The entire Tq trace was then low-pass filtered at 6Hz. EMG onset was
167 determined as the point where the EMG signal reached +2 SDs of the mean baseline activity of
168 the first 500 ms of the EMG record and stayed above that level for at least 100 ms.

169 All eight contractions were first scrutinized via their respective EMG and Tq traces so as to
170 eliminate those which did not comply with required characteristics. Reasons for rejection
171 included: unstable baseline, presence of significant agonist or antagonist activity prior to the
172 actual contraction, and improper execution (*i.e.*, markedly low Tq_{pk} or RTD_{pk} compared with
173 other trials). For each of the remaining contractions, Tq_{pk} and RTD_{pk} were calculated as
174 percentages of the highest Tq_{pk} and RTD_{pk} , respectively, attained by the participant in all
175 contractions. A composite score was calculated as the sum of the Tq_{pk} and RTD_{pk} percentages.
176 Out of those, the three contractions with the highest composite score were averaged and used for
177 further analysis. Only those contractions in which both Tq_{pk} and RTD_{pk} exceeded 80% of the
178 series' maxima were considered (see also: Mitchell *et al.* 2011). EMG and Tq data were analyzed
179 using MATLAB (The MathWorks, Natick, MA, USA).

180 **Torque-onset Determination**

181 Tq onsets were determined by visual inspection for each of the 1–3 selected contractions of
182 each participant. Times to reach given percentages of MVC were determined and averaged. The
183 time-to data were calculated for each percentage unit within the first 10% and then every ten
184 percent from 10 to 100% MVC. Group means were then calculated for each percentage point. The
185 RTD_{pk} value was determined for each contraction from the 2nd derivative of the original Tq trace.
186 Times to RTD_{pk} were calculated from the visually-determined Tq onsets and then averaged per
187 participant and per group. In conjunction with the synchronized EMG trace, EMD (time from
188 EMG- to Tq-onset) was individually determined and group means were calculated.

189 **Comparative threshold-determined Tq onsets**

190 Three TOD methods were compared in this study. In addition to visual TOD, two threshold
191 methods were examined: **a.** A fixed, absolute threshold of 4 Nm, identical for both men and boys,
192 represented typical baseline-noise-clearing thresholds; **b.** A relative, Tq-normalizing threshold of
193 5% MVC (means = 4.3, 12.9 Nm for the boys and men, respectively).

194 To determine the Tq-onset shifts (biases) produced by the 4 Nm- and 5% MVC-threshold-
195 based methods, a 6th-order polynomial best-fit Tq-time curve was calculated for each participant
196 from his respective 0–10% MVC mean time-points (mean R^2 values for the derived curves were
197 0.99993 and 0.99992 for the men and boys, respectively). From those polynomial equations, times
198 to 4 Nm and 5% MVC were individually calculated and then group-averaged. Figure 2 is a
199 schematic representation of this procedure.

200 [**Figure 2**]

201 **Statistical analysis**

202 Group differences in physical characteristics (Table 1) were examined using separate
203 independent t-tests.

204 Torque onset biases relative to visual determination were submitted to a 2-Group (Men,
205 Boys) by 2-TOD method (4 Nm, 5% MVC) mixed ANOVA with repeated measures on the final
206 factor. EMD data were submitted to a 2-Group (Men, Boys) by 3-TOD method (Visual, 4 Nm,
207 5% MVC) mixed ANOVA with repeated measures on the final factor. The time-to-tRTD data
208 were submitted to a 2-Group (Men, Boys) by 3-TOD method (Visual, 4 Nm, 5% MVC) mixed
209 ANOVA with repeated measures on the final factor. The time-to-%MVC data (*i.e.*, time to reach
210 10, 20, 30, 40, and 50% MVC) for the visually determined, 4-Nm threshold, and 5% MVC
211 threshold were submitted to three separate 2-Group (Men, Boys) by 5-% MVC mixed ANOVA
212 with repeated measures on the final factor in order to determine the time biases between the
213 groups depending on the onset determination method used. TOD was excluded as a factor in the
214 latter analysis. For each participant, the %MVC data is identified at the same location on the
215 torque trace and the type of TOD-method horizontally translates all the time-to-%MVCs by a
216 constant amount, thus resulting in the same between-subject variance for each TOD-method. The
217 comparison of relevance is whether there are detectable differences between Men and Boys
218 reaching their %MVC when using each TOD method separately.

219 Tukey's HSD with alpha set at 0.05 was used to decompose any main effects or significant
220 interactions involving more than two means. Data were analyzed using SPSS version 23.0 and are
221 reported as means with standard deviations.

222

223

224 **Results**

225 Peak torque (MVC) was three times greater among the men (257.4±91.2 Nm) than among the
226 boys (85.6±39.0 Nm), t(25)=6.33, p<0.001.

227 Figure 3 presents the threshold-derived onset biases relative to the visually-determined Tq
228 onsets. There were main effects of Group, $F(1, 25)=10.45, p<0.004$, TOD-method, $F(1,$
229 $25)=36.67, p<0.001$, and a significant interaction of Group and TOD-Method, $F(1,25)=47.78,$
230 $p<0.001$. The onset bias was shorter for the 4 Nm method among men than for the 5% MVC
231 method for men or either TOD-method for the boys. The 5% MVC method for men, the 4 Nm for
232 boys, and the 5% MVC method for boys produced similar onset biases. Of importance is that the
233 4 Nm method produced shorter bias for the men than the boys.

234 [**Figure 3**]

235 Analyses of the EMD revealed a main effect of TOD-Method, $F(2,50)=219.01, p< 0.001$, and
236 a significant interaction of Group and TOD-Method, $F(2,50)=19.44, p<0.001$. For the boys, using
237 the two threshold methods (4 Nm & 5% MVC), EMD values were similar, but produced longer
238 EMD than the visually derived method (Figure 4a). In the men, all three methods produced
239 different EMD values that increased from the visually determined to the 4 Nm method and then
240 increased again to the value of the 5% MVC method. EMD values were shorter for men than boys
241 for both the 4 Nm and 5% MVC methods. However, EMD was similar for men and boys using
242 the visually determined method.

243 [**Figure 4**]

244 Figure 4b depicts tRTD calculated from each of the three determination methods for both the
245 boys and men. Analyses of tRTD revealed a main effect of TOD method, $F(2,50)=219.01,$
246 $p<0.001$, and a significant interaction of Group and TOD method, $F(2.50)=19.44, p<0.001$.
247 Overall, tRTD was longer in the visually-determined onset method compared with the two
248 threshold methods. Additionally, the 4 Nm method resulted in longer tRTD than the 5% MVC

249 method. In the men, all three methods again produced different tRTD values that decreased from
250 the visually determined to the 4 Nm method and then decreased again to the values of the 5%
251 MVC method. For the boys, the visually determined method resulted in longer tRTD than the two
252 threshold methods that produced statistically similar times. When comparing the men and boys,
253 the 4 Nm method produced similar tRTD, but the 5% MVC and visually determined methods
254 produced shorter tRTD values for the men compared with the boys.

255 Figure 5 depicts the first 100 ms of the men's *vs.* the boys' Tq-kinetics (Tq-time plots) as
256 derived from Tq-onset determinations by the visual, 4 Nm, and 5% MVC TOD methods. The
257 analyses of the time to %MVC for the 4 Nm method revealed a main effect of Group,
258 $F(1,25)=7.96, p<0.009$, and a main effect of Percentage, $F(4,100)=504.76, p<0.001$. There were
259 only main effects of Percentage for the analyses of the visually determined, $F(4,100)=504.76,$
260 $p<0.001$, and 5% MVC methods, $F(4,100)=504.76, p<0.001$ (top and bottom charts, respectively).
261 Using the 4 Nm method, it took the men 14.9–18.0 ms longer than the boys to reach a given
262 %MVC during the first 100 ms (middle chart). There were no differences between men and boys
263 using either the visually determined or 5% MVC method.

264 [**Figure 5**]

266 **Discussion**

267 The present study reaffirmed the magnitude of the threshold-induced Tq-onset bias previously
268 shown in adults (de Ruyter *et al.* 2006; Thompson *et al.* 2012; Tillin *et al.* 2013a; Tillin *et al.*
269 2013b) and extended the findings to children. More importantly, the study demonstrated the
270 different magnitudes of these biases in men and boys, and that they can lead to fundamental
271 misinterpretation of results and erroneous conclusions **regarding** relative rates of force/torque

272 development. Such effects can be consequential not only in child–adult comparisons, but in any
273 comparison where one group’s maximal Tq or RTD is considerably different than that of the
274 reference group (typically, healthy adult-male participants). While our compared ‘special’ group
275 consisted of young boys, similar biases are to be expected when testing the elderly, the infirm, or
276 even when comparing males to females, athletes to non-athletes, *etc.* Moreover, similar biases
277 ought to be expected when comparing contractile characteristics of slower- vs. faster-contracting
278 muscles within the same individual.

279 Considering the observed absolute magnitude of threshold-based Tq-onset biases [from ~20
280 ms (Pain 2003) to much higher (~330 ms, (Soda *et al.* 2010))], it is perplexing that, to-date,
281 threshold-derived Tq-onset bias has not received much more attention. This may partly be due to
282 the fact that relevant research typically employs repeated measures of pre–post treatment-effects
283 on a given group of participants, or compares groups with similar contractile characteristics (*e.g.*,
284 two groups of adult men). In such cases, biases may be dismissed as systematic quantitative errors
285 that similarly affect all groups and may have little or no qualitative consequence on outcome
286 validity. We have demonstrated not only that large quantitative distortions may result when using
287 threshold TOD methods on weaker or slower participants (*e.g.*, children), but that highly
288 significant qualitative errors may result from comparing dissimilar groups.

289 Compared with the visual TOD, the 4 Nm-threshold method overestimated EMD by 37%
290 (18.3 ms) in the men, and by twice as much (73%, 40.3 ms) in the boys. Not only does a bias of
291 such magnitude place many individual values outside an acceptable physiological range, but it
292 renders the comparison between the two groups fundamentally invalid. For example, while the
293 visually-derived boys–men EMD difference of 5 ms was small (and statistically insignificant), it
294 quintupled by using the 4 Nm-threshold method (to ~27 ms, $p < 0.01$; Figure 4a).

295 While the boys' visually-based tRTD (like EMD) tended to be longer than the men's, the
296 boys–men difference (unlike EMD) did not increase under any of the threshold methods, but
297 rather decreased. This is due to the fact that while EMD is lengthened by threshold-derived onset
298 biases, tRTD is shortened by them. That is, the boys' slightly-longer visually-derived tRTD being
299 shortened more by their larger onset bias compared with the men. Although group differences
300 were not statistically significant with either of the two threshold methods, both resulted in
301 significant tRTD shortening. The 4 Nm-threshold method underestimated tRTD by 19% (18.4 ms;
302 $p < 0.05$) in the men and 28% (30.3 ms; $p < 0.001$) in the boys (Figure 4b).

303 When using a fixed-threshold method (*e.g.*, 4 Nm), the resulting onset biases may be of great
304 physiological significance. However, the qualitative misinterpretation and misrepresentation of
305 the findings could be qualitatively more consequential, as is clearly evident by the torque-kinetics
306 comparisons depicted in Figure 5. The reference, visually-based boys-*vs.*-men plots (top chart)
307 show the boys as having slightly slower kinetics. While that difference did not reach statistical
308 significance (likely due to high variability and small group sizes) it conforms to previous findings
309 of significantly slower Tq kinetics of boys compared with men (Cohen *et al.* 2010; Dotan *et al.*
310 2013a; Dotan *et al.* 2013b; Mitchell *et al.* 2011; Waugh *et al.* 2013). When derived via the 4 Nm-
311 threshold method, however, the interpretation is reversed (Figure 5, middle chart) and the boys
312 appear as reaching any MVC fraction faster than the men. For example, they reach 10% MVC
313 twice as fast and attain ~7% greater relative Tq at 60 ms (compared with the corresponding
314 visually-based value of ~2.5% MVC).

315 The findings of this study have important implications in evaluating the accuracy and often
316 the validity of previous research findings. Asai and Aoki (Asai and Aoki 1996) compared
317 'contraction delay' (akin to EMD) in men and 6-year-old boys, using a fixed threshold of ~1.1%
318 of the boys' MVC. Based on our findings (Figure 2) and the fact that the boys were much younger

319 and likely had lower MVCs than our boys, the estimated boys–men onset-bias difference must
320 have exceeded 10 ms. Presumably, this contributed to the boys’ exceptionally-high and physio-
321 logically questionable 140-ms contraction delay and likely also added ~20% to the reported ~50-
322 ms boys–men difference.

323 In a study by Waugh *et al.* (Waugh *et al.* 2013), EMD and RFD values were quantified in 5–
324 10-year-old children and adults, using a fixed-threshold method of +3SD baseline noise. The
325 resultant Tq-onset biases could have artificially increased the reported EMD values. As RFD
326 typically increases with age (Cohen *et al.* 2010; Dotan *et al.* 2013a; Dotan *et al.* 2013b; Mitchell
327 *et al.* 2011), we suggest that overestimation of EMD was largest among the youngest children.
328 Indeed, Waugh *et al.*’s mean adult EMD (50.4 ms) was similar to ours (50.1 ms), their
329 corresponding 9–10, 7–8, and 5–6 year-old values were 74.5, 77.4, and 96.0 ms, respectively,
330 compared with 55.1 ms for our 8.6±0.6 year-old boys. Moreover, segmental RFDs were
331 calculated between Tq onset and 50, 200, and 400 ms of contraction. Since the children’s onset
332 biases were presumably larger than the adult biases, their RFDs were measured from later points
333 and thus over steeper segments of their respective force-time curves. Namely, adults and children
334 were compared over dissimilar time-windows along the force-time curve, likely resulting in
335 overestimation of the children’s RFDs. We suggest, therefore, that the reported age-related RFD
336 differences were likely underestimated.

337 A recent study compared isometric leg-extension Tq and RTD of young *vs.* elderly men
338 (Jenkins *et al.* 2014). A fixed, 3Nm-threshold was used for Tq-onset and segmental RTD
339 determinations, similar to those used by Waugh *et al.*, above (Waugh *et al.* 2013). The authors
340 concluded that elderly men differ from their younger counterparts in peak Tq, but not in RTD.
341 Since RTD (RFD) has previously been shown to be lower in the elderly (*e.g.*, (Hakkinen *et al.*
342 1998)), we argue that, as with children (Figures 2, 3), the elderly’s Tq-onset bias was larger than

343 that of the younger men. Therefore, as in Waugh *et al.*'s child–adult comparison (Waugh *et al.*
344 2013), the elderly's segmental RTD likely corresponded to later time-windows along the torque-
345 time curves. This resulted in the elderly's artificially higher RTD values and presented as similar
346 RTD values for the two groups.

347 To avoid differential-bias issues, the 5% MVC-threshold aimed to normalize the men–boys
348 disparity in peak Tq by setting a fixed fraction of each individual's MVC. Indeed, while it could
349 not eliminate the onset biases, inherent to all threshold-based TOD methods, those did not
350 statistically differ between men and boys and directly corresponded with the visually-based
351 reference values (Figures 4, 5). Since the boys' mean 4 Nm and 5% MVC threshold values
352 happened to be very similar (Figure 2), there were no differences in their corresponding effects on
353 either EMD (Figure 4), or tRTD (Figure 4b). In the men, on the other hand, the 5% MVC
354 threshold constituted torques considerably greater than 4 Nm and consequently effected greater
355 deviations from the visually-derived values than those of the 4-Nm-based values, in both EMD
356 (Figure 4a), and tRTD (Figure 4b). Thus, the use of relative, normalizing thresholds, such as the
357 5% MVC, is more appropriate than the use of fixed thresholds (*e.g.*, 4 Nm) in comparing
358 disparate groups of participants, such as children *vs.* adults. Most previous studies have not used
359 normalized Tq-onset thresholds (*e.g.*, 5% MVC). This may be reflective of the relative scarcity of
360 disparate-group comparisons, but may also be indicative of the lack of appreciation of the
361 potential misinterpretation of findings.

362 It should be noted that, while the use of a normalizing threshold does avoid much of the
363 differential bias associated with disparate-group comparisons, it does not eliminate the onset bias
364 itself. Fixed thresholds (*e.g.*, 4 Nm), are typically designed to just clear baseline noise and they
365 thus minimize the loss of potentially relevant data. With normalizing threshold methods, the
366 stronger group's threshold is, by definition, correspondingly higher than baseline noise. In our

367 study's example, the segment on the men's Tq trace, between the boys' 4.3-Nm and the men's
368 12.9-Nm 5%-MVC-thresholds (Figure 2), constitutes data loss not due to baseline noise.

369 **Conclusions:** This study demonstrated that the method by which Tq onset is detected can
370 have important implications on comparisons between men and boys and, in general, between any
371 two groups of markedly dissimilar contractile characteristics (*e.g.*, Tq, RTD), particularly when
372 absolute, fixed thresholds are used (*e.g.*, 4 Nm). Implications may not be only quantitative, but
373 could result in qualitatively-erroneous conclusions. A relative, normalizing threshold (*e.g.*, 5%
374 MVC) is preferable to a fixed-threshold for disparate-group comparisons, although it does not
375 eliminate the potentially-important quantitative misrepresentations of torque kinetics and
376 contractile parameters. Therefore, it is recommended that whenever practically possible, visual
377 torque-onset determination be employed. When this is impractical, proper consideration of onset-
378 bias effects should be given in analysing and interpreting results.

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448

449 **Figure Legend**

450 **Figure 1** – Onset bias in the Threshold torque-onset detection method

451 **Figure 2** – Determination of the 4 Nm- and 5% MVC-threshold-derived torque onsets (onset
452 biases) for the men and the boys, relative to the visually-determined onset (0 on the X
453 axis). The plots and associated MVC values are group means. Actual determinations
454 were derived from individual data.

455 **Figure 3** – Threshold-effected torque-onset biases, relative to the visually-determined reference
456 values. Note the absolute magnitude of the biases (men: 18.4 ms; boys: 40.3 ms) and
457 the resultant, large boys–men difference (21.9 ms) with the 4 Nm threshold method.

458 * = $p < 0.001$

459 **Figure 4** – **4a:** EMD values based on visually- vs. threshold-determined torque onsets. Note the
460 particularly-large visual-vs.-threshold differences in the boys relative to the men.

461 **4b:** Times to RTD_{pk} based on visually- vs. threshold-determined torque onsets. Note
462 that differences are opposite of what they were in EMD (Fig.4a) due to the opposite
463 effect of the onset bias. § = $p < 0.01$, * = $p < 0.001$

464 **Figure 5** – Men–boys Tq-kinetics differences (initial 100 ms), based on torque-onset
465 determinations by the visual method (top chart), the 4 Nm-threshold method (centre
466 chart), and the 5% MVC-threshold (bottom chart). Torque (Y axis) is expressed as
467 %MVC to normalize the large strength differences between the two highly disparate
468 groups. Note that while the reference (visual) method depicts the men as possessing
469 slightly faster torque kinetics, the 4 Nm-threshold-derived plots suggest the boys as
470 having much superior kinetics. The boys–men differences virtually disappear when
471 the Tq-kinetics plots are based on the normalizing 5% MVC-threshold.

472

473 **Table 1** – Physical characteristics of the participants, presented as mean \pm SD (range).

474

	Men	Boys
n	12	15
Age, years	21.6 \pm 1.6 (19.4 – 23.7)	8.6 \pm 0.6 * (8.0 – 10.1)
Body mass, kg	84.5 \pm 7.1 (75.4 – 95.0)	32.0 \pm 5.3 * (24.7 – 41.9)
Height, cm	182.0 \pm 5.9 (174.6 – 193.6)	133.0 \pm 5.2 * (123.6 – 142.1)

475

476 * – Men vs. boys $p < 0.001$