Torque-Onset Determination: Unintended Consequences of the Threshold Method

Raffy Dotan[1], Glenn Jenkins[1], Thomas D. O'Brien[2], Steve Hansen[3], Bareket Falk[1]

1 – Faculty of Applied Health Sciences, Brock University, St Catharines, ON, Canada
2 – Research Institute for Sport and Exercise Sciences, Faculty of Science, Liverpool John Moores University, Liverpool, UK
3 – Physical & Health Education, Schulich School of Education, Nipissing University, North Bay, ON

Corresponding author:

Raffy Dotan
Faculty of Applied Health Sciences
Brock University
500 Glenridge Ave.
St Catharines, ON, Canada
L2T 2Y1
Tel: 905 688 5550 Ext.5257
Email: rdotan@brocku.ca

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Abstract

***Background*:** Compared with visual torque-onset-detection (TOD), threshold-based TOD produce onset bias, which increases with lower torques or rates of torque development (RTD). ***Purpose*:** To compare the effects of differential TOD-bias on common contractile parameters in two torque-disparate groups. ***Methods*:** Fifteen boys and 12 men performed maximal, explosive, isometric knee-extensions. Torque and EMG were recorded for each contraction. Best contractions were selected by peak torque (MVC) and peak RTD. Visual-TOD-based torque-time traces, electromechanical delays (EMD), and times to peak RTD (tRTD) were compared with corresponding data derived from fixed 4-Nm- and relative 5%MVC-thresholds. ***Results*:** The 5%MVC TOD-biases were similar for boys and men, but the corresponding 4-Nm-based biases were markedly different (40.3±14.1 *vs*. 18.4±7.1 ms, respectively; $p<0.001$). Boys–men EMD differences were most affected, increasing from 5.0 ms (visual) to 26.9 ms (4 Nm; $p<0.01$). Men's visually-based torque kinetics tended to be faster than the boys' (NS), but the 4-Nm-based kinetics erroneously depicted the boys as being much faster to any given %MVC ($p<0.001$). ***Conclusions*:** When comparing contractile properties of dissimilar groups, *e.g.*, children *vs.* adults, threshold-based TOD methods can misrepresent reality and lead to erroneous conclusions. Relative-thresholds (*e.g.*, 5% MVC) still introduce error, but group-comparisons are not confounded.

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

Abbreviations

ANOVA – Analysis of variance

EMG – Electromyography

EMD – Electro-mechanical delay

HSD – Honest significant difference

MVC – Maximal voluntary contraction

RFD – Rate of force development

RTD – Rate of torque development

RTD_{pk} – Peak rate of torque development

TOD – Torque-onset determination

Tq – Torque

tRTD – Time to peak rate of torque development

Conflict of Interest

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 Ruiter *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*
76 *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 Ruiter *et*
84 *al*. 2004; de Ruiter *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

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

[**Figure 1**]

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

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

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

Methods

Participants

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

[**Table 1**]

Study's Design

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

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

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

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

Torque Measurement

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

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

EMG Recording

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

EMG and Torque Data Acquisition and Analysis

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

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

Torque-onset Determination

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

Comparative threshold-determined Tq onsets

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

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

[**Figure 2**]

Statistical analysis

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

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

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

Results

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

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

[**Figure 3**]

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

[**Figure 4**]

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

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

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

[**Figure 5**]

Discussion

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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Figure Legend

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

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

Figure 3 – Threshold-effected torque-onset biases, relative to the visually-determined reference values. Note the absolute magnitude of the biases (men: 18.4 ms; boys: 40.3 ms) and the resultant, large boys–men difference (21.9 ms) with the 4 Nm threshold method. ***** = $p<0.001$

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

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

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

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

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476 ***** – Men *vs*. boys $p<0.001$