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In a previously published review article, Dotan et al (10), proposed the hypothesis of a differential motor-unit (MU) activation in children to account for many observed child–adult differences (ie, maximal strength, rate of force development, fatigue resistance, metabolic profile, and responses to training). Specifically, these authors pointed to Type II MU utilization as “being the compromised portion of children’s muscle function.” This review was previously commented on by Bassa et al (3) and O’Brien et al (25). In this comment, we propose to contribute to the ongoing debate on this topic. In particular, we will approach the question of MU recruitment from a methodological point of view to sum up our current knowledge and to identify the methodological steps that must be done to move forward on this topic.

Trying to infer MU utilization and recruitment from noninvasive investigation methods in children is challenging. Indeed, owing to obvious ethical considerations, the methodological approaches available to study MU recruitment and utilization noninvasively in children offer limited insights. Until now, the pediatric exercise physiologists have mainly used (1) the rate of force development, (2) surface electromyography (EMG), and (3) the twitch interpolation technique.

(1) Some authors have focused on the time course of explosive maximal voluntary contractions to compare MU recruitment in children and adults. Specifically, these studies have examined the rate of rise in contractile force at the onset of contraction, ie, the rate of force development (RFD) exerted within the early phase of rising muscle force (30–200 ms). Among the physiological factors that can affect RFD are muscle fiber type and myosin heavy chain composition (16), muscle cross-sectional area (2), maximal muscle strength (26), viscoelastic properties of the muscle–tendon complex (6,33), and neural drive to the muscle (1,12). If the confounding effects of muscle cross-sectional area and muscle strength can be discarded using appropriate normalization procedures, the relative contributions of viscoelastic and neural properties to the differences in RFD between children and adults are difficult to determine. Nevertheless, Waugh et al (32) recently demonstrated that tendon stiffness and the rate of EMG increase (ie, muscle activation rate) accounted for 35% and 30% of the variability of RFD in children, respectively. The relative contributions of tendon stiffness and rate of EMG increase may nonetheless vary during the course of force rise. Indeed, the influence of muscle activation rate appeared more important than tendon stiffness in the early stages of development of force in children, whereas the opposite was true for adults (32). This is consistent with the recent suggestions of Dotan et al (9). Nevertheless, Waugh et al (32) also demonstrated that when tendon stiffness and rate of EMG increase were combined, they explained only 58% of RFD variability, suggesting that other (unknown) factors are involved. Thus, RFD cannot accurately and fully reflect the extent of MU utilization and recruitment.

(2) The use of surface EMG to account for muscle activation is also debatable. Surface EMG quantifies muscle activity but does not determine the proportion of MU unrecruited or driven submaximally by the central nervous system (ie, muscle inactivation). As mentioned earlier, the ability of prepubertal children to maximally drive their MU is debated (3,5,10,20,25). If it holds true that children are not able to maximally recruit their MU, and especially the fastest (ie, Type II MU), peak EMG measured during voluntary contractions may represent a lower proportion of the maximal activation in children than in adults. In turn, this would bias the normalization of EMG activity used to determine the rate of muscle activation during explosive actions. Specifically, this could lead to an overestimation of the MU recruitment in...
children. The normalization of the EMG activity to the muscle compound action potential (M-wave) could partly reduce this bias, and the concurrent confounding effect of muscle mass, but M-waves are rarely reported in children (13,14).

To approach the extent of muscle inactivation, it is mandatory to trigger evoked contractions with electrical or magnetic stimulations. In the early 1950s, Merton (21) proposed the twitch interpolation technique, which consists in superimposing an evoked contraction (a single twitch in most of the studies conducted in children, although a double stimulation may be preferable) over a maximal voluntary contraction, generally performed in isometric condition. This superimposed response is subsequently compared with the response evoked on the relaxed muscle, with the same stimulus intensity. The outcome of this comparison is a percentage of MU inactivation, or by extension, the percentage of MU activation. This technique is the gold standard for the noninvasive measurement of the maximal voluntary activation level. It has been used successfully in children. Studies have used mainly electrical stimulation (4,5,14,29) but recently some studies have also used magnetic stimulation (20,24), which offers the great advantage of being painless. Its validity against electrical stimulation has also been established in children (23) and adults (31).

The cross-comparisons of maximal voluntary activation levels between children and adults have derived controversial results. The seminal studies found no difference between boys and male adolescents on the ankle flexors and extensors (4) or between children and male adolescents on the elbow flexors (5), but found a lower activation level of the knee extensor muscles in children as compared with male adolescents (5). Recently, a lower activation level was also reported on the adductor pollicis muscle in prepubertal boys compared with male adults (20). It seems that sex and age may affect voluntary activation differences between children and adults. Indeed, two studies compared prepubertal children and adults of both sexes (24,29). When sexes were pooled, both studies found a lower activation level on the knee extensor muscles in children. However, when examining the effect of sex, both studies found no difference of activation level between boys and men, but a significantly lower activation level in girls than in women. Finally, Grosset et al (14) observed that the maximal activation level of the plantar flexor muscles increased between 7 and 10 to 11 years of age, where maximal activation level was no longer different from adult values. This is quite consistent with the findings of Koh and Eyre (19) who studied the maturation of the corticospinal tract with transcranial magnetic stimulations in neonates, toddlers, children, adolescents, and adults and found that the excitability of the corticospinal tract increases dramatically between 8 and 11 years of age. In addition, these authors estimated that the conduction velocity within motor pathways reached adult values around 11 years of age. The methodological approach of this study is nevertheless questionable since transcranial stimulations were delivered on a relaxed muscle, a situation where corticospinal excitability is low compared with the contracting state.

Further studies are thus required to get a better understanding of MU recruitment in children. Should the ethical committees consider its application acceptable in children, the use of transcranial magnetic stimulation offers interesting perspective. The methodological of this technique has evolved since the late 1980s, and it is now possible to use the twitch interpolation technique with magnetic stimulations of the motor cortex (27,30). This offers the great opportunity to get an estimate of the excitability of the entire corticospinal tract. Other noninvasive approaches such as functional magnetic resonance imaging or near infrared spectroscopy of the motor cortex open new avenues for the noninvasive evaluation of the maturation of the motor pathways during childhood and adolescence.

If the twitch interpolation technique is the gold standard for the noninvasive measurement of the maximal voluntary activation level, it does not allow determination of what types of MU are driven submaximally by the central nervous system. Yet, according to the size principle (17), the Type II MU should be the last MU recruited during a maximal effort. Consequently, the MU driven submaximally or unrecruited by the central nervous system in individuals demonstrating an activation deficit should be Type I MU. But we cannot exclude that some Type I MU could also be activated submaximally. In addition, some deviations from the size principle have been observed in adults during lengthening (18,22) and ballistic contractions (11,15,34), such as those used to evaluate the RFD, but this topic remains highly controversial (7,8,28). To date, this topic is not documented in children. Therefore, it is currently unknown if the recruitment of MU differs in children between “nonexplosive” and “explosive” maximal contractions and between dynamic (ie, concentric and eccentric) and isometric contractions. Broadening our field of investigation to different types of contractions will help to get a better understanding of MU recruitment properties in children. Yet, in that respect, the methodological approaches currently available will offer limited insight. It is currently possible to quantify the muscle activity (with surface EMG) and the proportion of MU activated maximally (with the twitch interpolation technique), but it is impossible to determine noninvasively what type of MU is activated sub/maximally in children and adults. Methodological advances are, thus, required to verify the assumption that Type II MU utilization is “the compromised portion of children’s muscle function,” as proposed by Dotan et al (10).

References


31. Verges S, Maffioletti NA, Kerherve H, Decorte N, Wuyam B, Millet GY. Comparison of electrical and magnetic...

