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Opinion

Effort minimization: A permanent, dynamic, and surmountable influence on physical activity

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Today, most people know that physical activity (PA) is beneficial for their health[1,2] and aspire to engage in regular PA.[3,4] However, despite their awareness of the importance of PA, it is evident that the transition from intention to action is challenging—a situation that has important public health implications. According to the World Health Organization,[5] 1 person dies every 6 s worldwide from causes related to physical inactivity, which underscores the urgency of addressing this situation. Many factors have been identified that influence the translation of PA intentions into behaviors.[6] However, there is still considerable room for improvement in our understanding of this intention−behavior gap. In this endeavor, the Theory of Effort Minimization in PA (TEMPA[7]) has recently emerged as a heuristic theoretical framework capable of shedding light on the mechanisms underlying individuals' (in)ability to translate their intentions into actions.[8]

To expand TEMPA, in this paper, we first aimed to clarify 2 fundamental phenomena: (a) the permanent evolutionary drive to conserve energy, which is juxtaposed with (b) seemingly contradictory examples showing that some individuals have a natural urge to move more, especially children. We then highlighted how the strength of these general tendencies could evolve across the lifespan and as a function of biological sex. Finally, we elucidate the key roles of executive function and affective associations in overcoming the drive to minimize physical effort and promoting engagement in PA, and how these roles may vary across the lifespan and sex.

1. The permanent attraction to effort minimization and an evolutionary pressure toward energy conservation

One of the first questions that arises when the postulates of TEMPA are presented is the apparent contradiction that some individuals, especially children, appear to have a drive to move and expend energy. This drive is consistent with the recent Wants and Aversions for Neuromuscular Tasks (WANT) model, which posits a fundamental human need for PA.[9] While WANT and TEMPA share several commonalities, the primary divergence lies in their theoretical underpinnings: TEMPA, rooted in an evolutionary perspective, posits an innate tendency to avoid unnecessary physical effort, whereas WANT suggests that the attraction toward PA and sedentary behavior is largely dependent on situational factors. Although these 2 approaches may seem to be at odds with each other, we will explain why some individuals engage in high levels of PA despite a natural drive to avoid unnecessary physical effort.

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TEMPA contends that effort minimization is a permanent feature that influences multiple stages of the regulation of movement-based behaviors. This claim is supported by behavioral observations in which spontaneous choices reveal a tendency to minimize the amount of effort exerted. For example, when individuals need to move from one place to another, more than 90% of them will choose the escalator over the stairs.[10] Similarly, individuals tend to take shortcuts, such as crossing corners on lawns, in order to slightly reduce the distance (and time) traveled whenever possible.[11] Furthermore, decisions are influenced by the perceived cost of action, with individuals spontaneously preferring behavioral alternatives that minimize the effort required to perform the action, even without being aware of the mechanisms at work.[12] The observation that even when individuals choose the more costly option, such as taking the stairs instead of the escalator, the mechanism of effort minimization is still at work—with biomechanically efficient movement—further supports this tendency.[13,14] For example, humans constantly optimize the energetic cost of walking by adjusting various parameters such as walking speed, arm swing, and step length, width, and frequency.[13] In addition, the energetic cost of movement influences motor adaptation during the learning process, as demonstrated in young children who adapt their motor skills according to the energetic cost of movement.[14]

2. The dynamic attraction toward effort minimization across the lifespan and biological sex

In this section, we first provide a brief explanation of how dispositional and situational factors can moderate the impact of effort minimization mechanisms on the regulation of PA. Subsequently, we delve into how age and biological sex may also serve as significant moderators.

2.1. Situational and dispositional factors

In the seminal article introducing TEMPA, Cheval and Boisgontier[7] suggest a permanent (i.e., at every moment of the lifespan) evolutionary pressure toward the principle of energy conservation. However, this does not imply that the influence of this pressure on behavioral regulation is stable across ageing (see below) nor across individuals and situations. In fact, TEMPA incorporates the influence of dispositional and situational factors on the principle of effort minimization. Specifically, regarding dispositional factors, TEMPA postulates the existence of interindividual differences in this tendency.[15] For example, individual differences in approaching (*vs*. avoiding) physical effort act as a moderator of the intention−behavior gap; the association between intention and PA was stronger for individuals with a stronger tendency to approach (*vs*. avoid) physical effort.[16] Regarding situational factors, TEMPA argues that physiological states such as fatigue or timing of the most recent PA (e.g., performed in the last hours or days) are particularly important. For example, when individuals are fatigued, they may perceive a behavior as requiring more effort than when they are not fatigued. These situational factors account for the dynamic nature of effort minimization. Nevertheless, as explained in the section above, the tendency to minimize effort is theoretically never null, as exemplified by the biomechanically efficient nature of a behavior or the process of motor adaptation during learning. Because they have been addressed in the original article,[7] this article will not further discuss the role of these factors in influencing the strength of the influence of effort minimization on behavior. Instead, we will focus on an aspect of TEMPA that has been little discussed until now: the influence of lifespan and sex on effort-minimization mechanisms. However, the attentive reader will understand that dispositional factors and situations can also modulate the mechanisms that will be discussed below.

2.2. Lifespan and sex

From an evolutionary and life-history perspective, the importance of effort minimization on movement-based behaviors is expected to change across the lifespan. Childhood provides a unique opportunity for PA free of energetic trade-offs, without direct investment in reproductive effort or pressing demands to produce food for oneself or one's family.[17] Consequently, at this early life stage, most of a child's energy can be devoted to physical (e.g., muscle and bone development, strengthening of the immune system), cognitive (e.g., skill acquisition and brain maturation), and social growth (e.g., refinement of social skills). The benefits of PA during this stage of life are important because movement is fundamental in helping children construct their perceptions of their environment and is, therefore, inherently intertwined with their development. Futhermore, engaging in playful activities with others fosters strategic thinking and contributes to the development of social skills that are essential for living together in a society.[18,19] These multiple benefits associated with PA may contribute to children's natural inclination to engage in PA during play,[20] which should not be misinterpreted as a natural tendency to move just for the sake of moving, with no other expected reinforcing outcomes. Indeed, as mentioned earlier, the principle of effort minimization operates in children's movement, whereby a child's movement becomes more efficient with practice and learning (e.g., ambulatory patterns become more efficient as children learn walking skills[14]). Conversely, during puberty, the pressure to conserve energy gradually increases as more energy is required for sexual maturation and accelerated body growth.[21,22] Consistent with this, studies have shown a decline in PA levels during this period, particularly in females who enter puberty earlier than males[23–25] or among females who mature earlier than their peers.[26,27] In addition, these findings are consistent with other studies indicating that once pubertal maturation of adolescents is considered, sex differences in the decline of PA become less pronounced.[28,29]

In adulthood, energy is no longer primarily allocated to body growth but shifts to support reproduction, especially in females.[30,31] Therefore, the physiological stress experienced during pregnancy or after childbirth may contribute to the decline in PA among females during these periods.[32,33] This decline is less pronounced in males, whose reproductive physiology imposes lower and more stable energetic costs.[34,35] Finally, in older adulthood, the pressure to conserve energy may decrease due to differences in reproductive and survival strategies,[36,37] thereby allowing more energy to be spent in PA at this stage (albeit within age-related functional limitations). For example, evidence from Hadza hunter-gatherers suggests that post-reproductive females engage in approximately 20% more foraging activities than younger mothers, spending additional time on tasks such as food preparation, digging, walking, and carrying.[36] Consequently, hunter-gatherer grandparents may contribute excess energy to support their children and grandchildren.[37] Thus, at this stage, this relative increase in PA appears to be driven by a mechanism that ensures sufficient energy availability at the group level to ensure reproductive success.

Crucially, empirical evidence on the prevalence of physical inactivity across the lifespan is consistent with the postulates of TEMPA. Specifically, data suggest that levels of PA decline significantly from childhood to adolescence, with sex differences emerging as girls report lower levels of PA than boys during this period. While levels of physical inactivity are less pronounced in young adulthood compared to adolescence, they increase significantly after age 60.[24,38,39] It is important to acknowledge that, in this section, we focused on the biological aspect of sex differences in energetic pressure. However, an attentive reader must understand that these changes are also strongly intertwined with the socio-cultural aspect of gender—with girls and women receiving less support to engage in PA throughout their lifespan.[40] Thus, the focus in this opinion on the intraindividual forces that motivate people's behaviors should not overshadow the importance of the role of environmental factors in regulating PA behavior, as suggested by socioecological models.[41,42]

In sum, although the pressure to conserve energy is not as relevant in today's industrialized societies, the principle of energy minimization is thought to persist and influence behaviors. As a result, there may be a mismatch between our evolutionary legacy, which was adaptive during periods of potential food scarcity, and the current environment, in which this heritage may now prove detrimental in contemporary societies. Understanding how to engage in PA despite this drive to minimize effort is therefore necessary if we hope to address the current inactivity pandemic.

3. Executive function and affective associations toward PA across the lifespan and sex

In a recent editorial,[8] we argue that 2 key pathways can be mobilized to promote engagement in PA in the contemporary environment, where opportunities to minimize energy expenditure are ubiquitous: (a) the motivation to use available executive functions to overcome impulses to minimize effort, and (b) the development of positive affective associations toward PA. Here, however, we delve deeper into these mechanisms by suggesting that the role of these 2 pathways may vary depending on age and sex. Indeed, it can be hypothesized that the pressure to conserve energy, the maturity of executive function, and the perceived effort associated with a given behavior would vary across the lifespan and between sexes.

In the case of children, the cognitive functions are not yet fully developed, but they are also faced with relatively low energy pressure. In this context, it is plausible to assume that executive function does not play a determining role in explaining their engagement in PA, while affective associations could, on the contrary, be of greater importance. At this stage, no sex differences are expected in relation to this evolutionary influence. It is assumed that the observed differences in PA levels are mostly a consequence of the different treatment of boys and girls at the socio-cultural level.[40] However, in adolescence, while executive function remains immature, there is also a high pressure to conserve energy due to sexual maturation and accelerated body growth. This still-developing executive function, combined with a high pressure to conserve energy, can largely explain the lack of engagement at this stage—80% of adolescents do not meet the recommendations.[43] According to TEMPA, at this specific period, we need to ensure that adolescents develop positive affective associations toward PA to build a drive to engage in such effortful activities (i.e., the cost of effort must be balanced by immediate and tangible rewards).[44]

In adulthood, the pressure to conserve energy depends on sex, with females experiencing a stronger and more labile pressure than males due to a sexually patterned energetic demand for reproduction.[32,33] At this stage, however, executive function is mature and can be used to overcome this impulse toward behaviors that minimize energetic cost. Here, it can be expected that the use of executive function could be quite effective, at least in the short term, but that this executive function would need to be complemented by strong positive affective associations associated with PA, perhaps especially among females. These sex differences in the pressure to conserve energy are consistent with the observation that adult females typically engage in less moderate−vigorous PA than their male counterparts.[40,45,46] Finally, in older age, although the strong selective pressure is expected to diminish, there is also a decline in executive function combined with an increased cost of effort associated with a given behavior due to a decline in physical fitness and functional physical limitations. Thus, relying solely on executive function in this situation could be a precarious strategy because of the high cost of effort and the decline in cognitive function. Accordingly, maintaining executive function is necessary in older adults, but positive affective associations may play a key role in sustaining engagement in PA.

The mediating role of perceived cost of effort on the link between the evolution of the pressure to conserve energy and the evolution of PA across the lifespan and according to sex, as well as the role of executive function and affective mechanisms in overcoming this cost of effort, is summarized in Fig. 1. In short, the regulation of PA among children and adolescents may mostly rely on affective mechanisms, with adolescence being a problematic period due to high energetic pressure combined with immature executive function. Adults may rely on executive function (although not optimally for

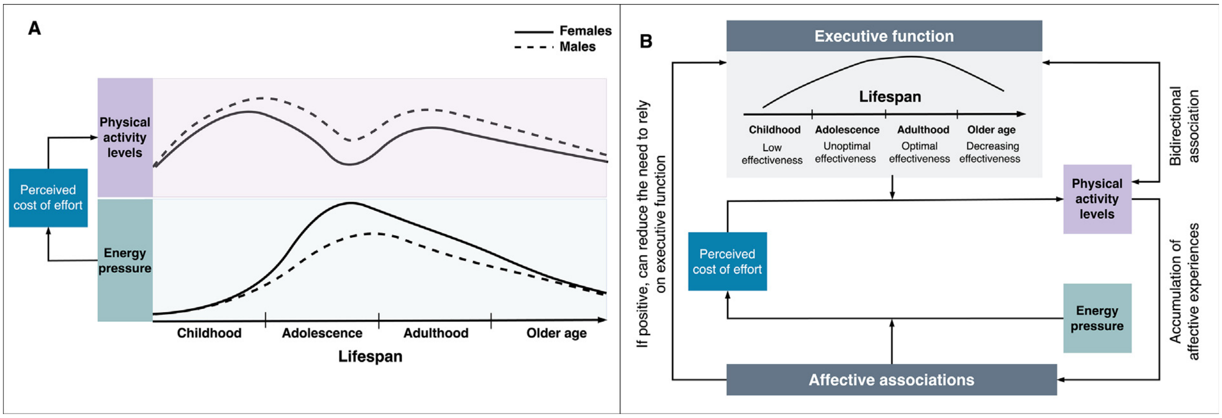

Fig. 1. Effort minimization across the lifespan and biological sex. (A) the permanent and dynamic influence of effort minimization; (B) the surmountable influence of effort minimization. According to TEMPA, when affective associations with physical activity are positive, there is a reduced need to rely on executive function to moderate the effect of perceived effort cost on physical activity levels. TEMPA = Theory of Effort Minimization in Physical Activity.

long-term maintenance of PA) but may also need to associate PA with positive affective experiences. Finally, older adults need to rely on strong affective associations, especially as their executive function and physical fitness decline across ageing. Although recent studies have confirmed the role of cognitive function in predicting PA participation,[47–49] to the best of our knowledge, no research has yet provided direct empirical evidence on how age moderates the strength of the relationship between cognitive function and PA. Future research is also needed to longitudinally examine how affective associations evolve across ageing and between sexes.

4. Conclusion

Although the mechanism of effort minimization varies across the human lifespan and between females and males, it remains a powerful factor that not only reduces the likelihood of engaging in PA but also ensures a minimal level of energy expenditure once engaged in PA. Crucially, despite this natural drive to avoid unnecessary physical effort, individuals can engage in high levels of PA. This is exemplified by children, who may appear to have a natural "drive to move", which is actually an urge to acquire the basic and essential elements necessary for their development, as well as to accumulate positive affective experiences. At other stages, cognitive and affective mechanisms may jointly explain why people are (un)able to overcome the impulse to minimize effort and to engage in PA. Thus, high levels of engagement in PA do not challenge the general principle of effort minimization. In summary, effort minimization is a permanent (i.e., the principle of optimization is still at work even during movement), dynamic (i.e., the strength of this process may differ across ageing and depending on situational and dispositional factors), and surmountable (i.e., using executive function and developing positive affective associations) tendency that influences multiple dimensions of the regulation of PA.

Authors' contributions

SM, LF, and BC conceived the study and wrote the original draft; QY, ZZ, YC, OD, RSF, NO, and LZ contributed to the improvement of the manuscript and approved its final version. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

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