Preseason aerobic and anaerobic tests for prediction of alpine skiing performance: a molecular perspective

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Alpine ski racing is a demanding and multifaceted sport requiring high levels of physical and technical competence.¹ Because of the complexity of the sport, the selection of useful sport-specific tests of physiological capacities is challenging.¹ Aerobic capacity is commonly measured using incremental cycle ergometer exercise, while anaerobic capacity is commonly tested using metabolically highly demanding all-out Wingate cycling.² High aerobic/anaerobic capacity of an elite alpine skier is considered an important physiological determinant of competitive success.² However, new findings on the molecular basis for exercise-induced fatigue do not support this assertion.^{3–6}

The contractile function of skeletal muscle declines during intense or prolonged physical exercise, that is, fatigue develops.³ Within the muscle fibres, fatigue is generally related to increased energy demands, in which effective ATP resynthesis is needed to match the dramatically increased ATP consumption during contractions.³ In contracting muscle fibres, ATP is mainly consumed by actomyosin cross-bridges and the sarcoplasmic reticulum Ca^{2+} pumps.³ Adequate ATP delivery to the ATP-consuming proteins is essential for normal cell function and integrity.³ Obviously, mechanisms to prevent these catastrophic consequences of ATP depletion exist within the muscle fibres.³ These mechanisms involve, on the one hand, effective metabolic systems to resynthesise ATP and, on the other hand, a fatigue-induced decline in ATP consumption.³ The latter fatigue mechanisms, which inhibit contraction-dependent ATP consumption, are a major focus of a recent review.³ Examples of exercises in which different fatigue mechanisms might limit performance are given in table 1 of the review by Cheng *et al.*³ Importantly, these different fatigue mechanisms might limit performance in metabolically demanding exercises.

For example, increased production of reactive oxygen/nitrogen species (ROS) and impaired cellular Ca^{2+} handling are implicated in prolonged force depression observed in skeletal muscle after metabolically highly demanding all-out Wingate cycling.⁴ Moreover, muscle biopsies taken 24 hours after high-intensity cycling exercise show an extensive fragmentation of the sarcoplasmic reticulum Ca^{2+} channels, the ryanodine receptor 1 (RyR1).⁴ Interestingly, elite endurance athletes develop a prolonged force depression after metabolically highly demanding all-out Wingate cycling, but no ROS-dependent RyR1 fragmentation.⁴

By contrast, prolonged force depression after mechanically demanding eccentric contractions (100 drop jumps from a height of 0.5 m) is largely independent of Ca^{2+} and ROS, and RyR1 fragmentation is observed in only some recreationally active elderly subjects.⁵ However, the force depression was not more marked in these subjects.⁵ Moreover, force depression after mechanically demanding eccentric contractions are similar in both recreationally active subjects and endurance trained athletes, despite the antioxidant capacity being higher in endurance trained muscles.⁵ Thus, the mechanisms underlying prolonged force depression after mechanically demanding eccentric contractions are dissimilar to those after metabolically highly demanding all-out Wingate cycling.

In addition, eccentric muscle activity is a titin based and not an O_2 ATP coupled contraction form. Shortly, when the sarcomeres of a skeletal muscle are stretched, for example, by gravitational forces, the titin immunoglobulin (Ig) domain segments and the PEVK region (The PEVK region is a titin spring element, which is rich in proline (P), glutamate (E), valine (V), and lysine (K) residues and is considered to be an intrinsically disordered protein region) extend.⁶ Titin domain folding against a force represents a potential source of work production in

muscles, which presumably acts synchronously with the actomyosin contractile mechanism.⁶ This way, titin is an active component in the sarcomere that helps to maximise work output without consuming ATP.⁶ Titin as a force generating muscle protein is a major focus of a recent review.⁶ Titin Ig domain refolding under force as a source of work production speaks against ATP depletion as a central factor underlying the impaired contractile function after mechanically demanding eccentric contractions.

Alpine skiing can arguably be characterised as the only sport in which well-coordinated eccentric muscle action is the decisive element.⁷ Eccentric muscle contraction is essential for opposing the high centrifugal forces experienced by skiers in carved turns.⁷ Carved turns of successful skiers are characterised by a short and distinct eccentric steering phase.⁷ Well-coordinated eccentric muscle activation is thus a key feature for success in competitive alpine skiing.⁷ Consequently, the mechanisms underlying force depression after ski racing are similar to those after mechanically demanding drop-jump exercise.⁵

Fatigue develops rapidly during physical activities requiring a rate of ATP production that exceeds the aerobic capacity of the muscle fibres.³ This type of fatigue is closely related to the need for ATP production by anaerobic metabolism,³ for example, metabolically highly demanding all-out Wingate cycling. Anaerobic metabolism leads to accumulation of lactate and hydrogen ions and increased blood lactate concentrations were measured after alpine ski racing without affecting competitive performance.^{1 3} However, the high metabolic loads experienced by alpine skiers essentially stem from the simultaneous activation of a plethora of trunk muscles necessary to maintain core stability and balance.⁷ Moreover, a recent study shows that recreational alpine skiing is associated with prolonged eccentric quadriceps and hamstring fatigue.⁸ Interestingly, concentric types of endurance training (metabolically demanding exercises) (eg, biking) do not prevent fatigue during eccentric

(ie, skiing) types of endurance exercise (mechanically demanding exercises).⁸

Based on these findings and in agreement with a recent study, we suggest that preseason aerobic and anaerobic tests are of limited use for prediction of alpine skiing performance.¹ A valid and reliable test battery that can predict performance in alpine skiing seems to be lacking. Therefore, future research directed towards screening for valid components of athletic performance is required.¹

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REFERENCES

1. Nilsson R, Lindberg A-S, Theos A, *et al*. Aerobic variables for prediction of alpine skiing performance – a novel approach. *Sports Med Int Open* 2018;02:E105–12.
2. Ferland P-M, Comtois AS. Athletic profile of alpine Ski racers: a systematic review. *J Strength Cond Res* 2018;32:3591–600.
3. Cheng AJ, Place N, Westerblad H. Molecular basis for exercise-induced fatigue: the importance of strictly controlled Cellular Ca²⁺ handling. *Cold Spring Harb Perspect Med* 2018;8.
4. Place N, Ivarsson N, Venckunas T, *et al*. Ryanodine receptor fragmentation and sarcoplasmic reticulum Ca²⁺ leak after one session of high-intensity interval exercise. *Proc Natl Acad Sci USA* 2015;112:15492–7.
5. Kamandulis S, de Souza Leite F, Hernández A, *et al*. Prolonged force depression after mechanically demanding contractions is largely independent of Ca²⁺ and reactive oxygen species. *Faseb J* 2017;31:4809–20.
6. Hoppeler H. *Eccentric exercise. Physiology and application in sport and rehabilitation*. London: Routledge Research in Sport and Exercise Science, 2014: 138–44.
7. Freundt JK, Linke WA. Titin as a force generating muscle protein under regulatory control. *J Appl Physiol*;104.
8. Koller A, Fuchs B, Leichtfried V, *et al*. Decrease in eccentric quadriceps and hamstring strength in recreational alpine skiers after prolonged skiing. *BMJ Open Sport Exerc Med* 2015;0:e000028.