The Influence of Exercise Modality on Training Load Management

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Exercise modality and training load management

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Abstract

Purpose: To provide novel insight regarding the influence of exercise modality on training load management by: 1) providing a theoretical framework for the impact of physiological and biomechanical mechanisms associated with different exercise modalities on training load management in endurance exercise, and 2) comparing effort-matched low-intensity training sessions performed by top level athletes in endurance sports with similar energy demands.

Practical Applications and Conclusions: The ability to perform endurance training with manageable muscular loads and low injury risks in different exercise modalities are influenced both by mechanical factors, as well as muscular state and coordination which interrelate in optimizing power production while reducing friction and/or drag. Consequently, the choice of exercise modality in endurance training influence effort beyond commonly used external and internal load measurements and should be considered alongside duration, frequency and intensity when managing training load.

By comparing effort-matched low-to-moderate intensity sessions performed by top level athletes in endurance sports, this study exemplifies how endurance exercise with varying modalities leads to different tolerable volumes. For example, the weight-bearing exercise and high impact forces in long-distance running puts high loads on muscles and tendons, leading to relatively low training volume tolerance. In speed skating, flexed knee and hip position required for effective speed skating leads to occlusion of thighs and low volume tolerance. In contrast, the non-weight-bearing, low-contraction exercises in cycling or swimming allows for large volumes in the specific exercise modalities. Overall, these differences have major implications on training load management in sports.

Keywords: Aerobic training specificity; training mode; loading factors; training organization.

Introduction

Training load management is crucial for the optimization of athlete training responses, competition readiness and for minimizing the risk of injury, illness, and non-functional overreaching.[1] Training load is traditionally determined by a series of components, such as training volume (duration), intensity and frequency, with subsequent adaptations interplaying with recovery periods, which have been heavily investigated in previous research literature.[2-19] In contrast, the influence of exercise modality on training load management remains relatively unexplored.

External training load is defined as the physical work performed and is commonly measured as distance, speed or power, while internal load corresponds to the psychophysiological response initiated to cope with the requirements elicited by the external load.[20] Since different exercise modalities are used to solve different constraints, their efficiency also differs, and the comparison of external powers cannot be interpreted. Moreover, energy expenditure comparisons across movement modalities are challenging to perform, and the concepts of external and internal load do not have a single or gold standard measure that can be used across modalities.[20] In addition, modality-specific factors such as mechanical loading of local muscles and tendons as well as muscular occlusion and load-recovery during the movement cycle would influence the ability to maintain exercise over time.

In this invited commentary, we aim to provide novel insight in the influence of exercise modality on training load management by: 1) providing a theoretical framework for the impact of physiological and biomechanical mechanisms associated with different exercise modalities on training load management in endurance exercise, and 2) comparing effort-matched low-intensity training sessions performed by top level athletes in endurance sports with similar energy demands. Specifically, we compare long-distance running, road cycling, swimming, rowing, cross-country (XC) skiing and speed skating, which are disciplines with ≥ 6-7 min competition duration with an aerobic energy contribution of ≥ 85%.

Theoretical framework

Technique in different exercise modalities are optimized for solving the constraints in a given sport. Indeed, different exercise modalities and inherent technical solutions will influence the efficiency of producing power, in which many aspects such as muscular state, mechanical and coordination factors interrelate. However, in many endurance sports the ability to produce high power is necessary, but not sufficient to maximize performance; reducing friction or air drag to additionally increase speed requires movement solutions that may influence load on local muscles and tendons, muscular occlusion as well as recovery-unloading during the cycle. Figure 1 illustrates this complexity.

Figure 1 about here

Such factors would influence circulation and thereby the ability to sustain power with manageable muscular loads and low injury risks. Consequently, the choice of exercise modality in endurance training will affect the cardiovascular and muscular effort beyond those measured by commonly used external and internal load monitoring systems. In addition, the tolerable amount of repetitions without causing structural damage/overload differs across modalities. Accordingly, duration of typical training sessions within the different intensity zones, the need for using alternative training modalities and solving the training program puzzle will therefore be highly influenced by the choice of exercise modalities.

Training comparisons of world-class athletes in endurance sports

To shed further light on the influence of exercise modality on training load in typical endurance sports, we compare effort-matched training sessions at low intensity (to assure aerobic steady state and comparable intensities) and total tolerable training volume in sport-specific modalities of world-class athletes (Table 1). We apply the above-presented framework to explain the underlying mechanisms.

Table 1 about here

For long-distance running, the combination of weight-bearing exercise and rapid plyometric power production puts high loads on muscles and tendons during each step. Accordingly, both the total running volume and the duration of low-intensity sessions are relatively low compared to the other endurance sports.[2-19] For example, most low-intensity sessions among elite athletes in the heaviest preparation period are approximately 1 h, although most athletes perform one weekly "easy long run" lasting 1:30-2:00 h. [2,3,6] The fact that running on forgiving surfaces and in soft terrain allows for longer sessions and much larger training volumes indicates that the running movement *per se* is not the main contributor to limited training tolerance, but that the interaction with running on a hard surface leading to high impact forces during the landing phase plays a role of importance. In order to obtain a relatively high training load in running, athletes seem to compensate by running twice a day and perform some of the low-intensity sessions in the upper range of the intensity zone, keeping the volume at moderate and high intensity relatively high.[3,6]

In contrast to long-distance runners, road cyclists can perform large bike training volumes. Typical total cycling volumes are 30-35,000 km per year, corresponding to 900-1000 h.[8-10] Women cyclists seem to exercise ~20% less than men,[10] likely explained by shorter competition distances and fewer women being professionals. Typical duration of low intensity cycling sessions are 4-5 h for men and ~3 h for women,[8-10] which is at least three times the duration compared to running. However, while runners train twice per day, cyclists often apply one daily cycling session. The concentric movement in a non-weight bearing exercise is a clear candidate as the main mechanism explaining the enduring of such large cycling sessions. In addition, the longer competition duration in cycling reinforces the need for sustained low-intensity sessions. An additional explanation may be that cyclists can draft behind teammates/competitors and thereby reduce the power output considerably.

Rowing is another non-weight-bearing exercise with long contraction time performed in a mainly concentric movement pattern. However, while world-leading rowers perform similar volumes as cyclists (i.e., up to 1100 h per year), only half of this is rowing.[11-13] Accordingly, rowers seldom row more than 50 h each month and 12-14 h each week. Although virtually nothing has been reported about types of sessions in the current literature, our practical working experience with rowers reveals that the typical duration of low-intensive rowing sessions is 60-90 min most likely due to high muscular load when rowing, which may increases the injury risk of e.g. overloaded back and elbows. However, rowers compensate their “low” specific volume by adding other exercise modalities. For example, a 1-h rowing session can be immediately followed by a 2-h cycling session. Such use of non-specific training has been shown effective for inducing performance gains and, at the same time, reduce the risk of injury/overload associated with more sport-specific training, although the performance gain *per se* may be less than doing more specific training.[21]

The non-weight-bearing, low contraction velocity movement of swimming allows for similar training volumes as cycling and rowing, mainly consisting of specific training.[14] While the literature presents limited information regarding typical sessions among elite swimmers, our experience is that these athletes typically perform low-intensive, specific sessions as micro-intervals, distributed between morning and afternoon sessions. Accordingly, most low-intensity sessions last 60-90 minutes, with approximately one weekly session lasting 2 h.

Cross-country skiing includes two main styles, classic and skating, and skiers distribute training time between many different sub-techniques within these styles while skiing on snow or using roller skis.[15-18] Although training can be distributed across these modalities and running, which is the main type of cross-training, the best athletes do not train more than cyclists, rowers or swimmers. The main reason for this may be the moderately high muscular loads of skiing uphill and the mental strain focusing on a good technique in this complex movement. In addition, cross-country sessions fluctuate between increased intensity uphill and reduced intensity downhill, which is somehow similar to the low-intensity micro-intervals in swimming. Overall, elite cross-country skiers train 800-1000 h each year, of which approximately 60% of the training is specific.[15-18] Typical duration of low-intensity ski sessions is 1.5-2.5 h, but most skiers have one or two weekly sessions of ~3-4 h.[15-18]

The leg movement pattern in speed skating bears great resemblance with XC-skiing. However, the distribution of specific training is substantially different, as speed skaters train only ~200 h each year on ice. This may be partly influenced by the limited possibility to train on ice but is primarily due to the intermittent blood-flow restriction when speed skating in a relevant position. Orie et al.[20] states that speed skating is different from other endurance sports due to the small angles in hip and knee in combination with a static body position and a long duty cycle of the skating stroke. Therefore, the high load on muscles additionally induce high anaerobic metabolism in the working muscles, and few pure skating sessions last more than 60 minutes. In addition, both warm-up and cool-down are performed on a cycling ergometer and the skating sessions are carried out as intervals, even at low intensity.

The training comparisons in this paper are based on low-intensity training sessions performed by world-class contestants. Although training sessions at higher intensities are designed to mimic the specific demands of a sport (e.g. competition duration), many of the differences presented for low-intensity sessions across sports can also be seen during moderate- and highintensive sessions. For example, typical accumulated work duration associated with long-interval sessions in world-class long-distance runners rarely exceed 30-40 min, while corresponding duration for cyclists and XC-skiers may reach 60-75 min.[6-10, 15-18]

Practical Application and Conclusions

This commentary provides a framework regarding the influence of exercise modality on training load management and suggests potential explanations for differences in duration of effort-matched low-intensity sessions performed by top level athletes in different endurance sports. The ability to perform endurance training with manageable muscular loads and low injury/overload risks in different exercise modalities are influenced both by mechanical factors, as well as muscular state and coordination which interrelate in optimizing power production while reducing friction and/or drag. Consequently, the choice of exercise modality in endurance training influence effort beyond commonly used external and internal load measurements and should be considered alongside duration, frequency and intensity when managing training load. While we suggest some explanations for the differences seen in sport practice, disentangling the factors that determine load in the various modalities needs further examination.

By comparing effort-matched low-to-moderate intensity sessions performed by top level athletes in endurance sports, this commentary exemplifies how endurance exercise with varying modalities leads to different tolerable volumes. For example, the weight-bearing exercise and high impact forces in long-distance running puts high loads on muscles and tendons, leading to relatively low training volume tolerance. In speed skating, flexed knee and hip position required for effective speed skating leads to occlusion of thighs and low volume tolerance. In contrast, the non-weight-bearing, low-contraction exercises in cycling or swimming allows for large volumes in the specific exercise modalities. Overall, these differences have major implications on training load management in sports.

References

1. Halson S. Monitoring training load to understand fatigue in athletes. *Sports Med*. 201;44:139-47.
2. Billat VL, Demarle A, Slawinski J, Paiva M, Koralsztein JP. Physical and training characteristics of top-class marathon runners. Med Sci Sports Exerc. 2001;33:2089–97.
3. Kenneally M, Casado A, Gomez-Ezeiza J, Santos-Concejero J. Training intensity distribution analysis by race pace vs. physiological approach in world-class middle- and long-distance runners. Eur J Sport Sci. 2020 Jun 20:1-8.
4. Casado A, Hanley B, Santos-Concejero J, Ruiz-Pérez LM. World-class long-distance running performances are best predicted by volume of easy runs and deliberate practice of short-interval and tempo runs. J Strength Cond Res. 2019 [Online ahead of print].
5. Billat V, Lepretre PM, Heugas AM, Laurence MH, Salim D, Koralsztein JP. Training and bioenergetic characteristics in elite male and female Kenyan runners. Med Sci Sports Exerc. 2003;35:297-304.
6. Enoksen E, Tjelta AR, Tjelta LI. Distribution of training volume and intensity of elite male and female track and marathon runners. Int J Sports Sci Coach. 2011;6:273-93.
7. Tjelta LI. The training of international level distance runners. Int J Sports Sci Coach 2016;11:122–34.
8. Zapico AG, Calderon FJ, Benito PJ, Gonzalez CB, Parisi A, Pigozzi F, et al. Evolution of physiological and haematological parameters with training load in elite male road cyclists: A longitudinal study. J Sports Med Phys Fitness 2007;47:191–6.
9. Svendsen IS, Tønnesen E, Tjelta LI, Ørn S. Training, performance, and physiological predictors of a successful elite senior career in junior competitive road cyclists. Int J Sports Physiol Perform. 2018 [Online ahead of print].
10. van Erp T, Sanders D, de Koning JJ. Training characteristics of male and female professional road cyclists: A 4-year retrospective analysis. Int J Sports Physiol Perform. 2019 [Online ahead of print].
11. Fiskerstrand A, Seiler KS. Training and performance characteristics among Norwegian international rowers 1970-2001. Scand J Med Sci Sports. 2004;14:303-10.
12. Gullich A, Seiler S, Emrich E. Training methods and intensity distribution of young world class rowers. Int J Sports Physiol Perform. 2009;4:448-60.
13. Bourgois J, Steyaert A, Boone J. Physiological and anthropometric progression in an international oarsman: a 15-year case study. Int J Sports Physiol Perform. 2014 Jul;9(4):723-6.
14. Hellard P, Avalos-Fernandes M, Lefort G, Pla R, Mujika I, Toussaint JF, Pyne DB. Elite swimmers' training patterns in the 25 weeks prior to their season's best performances: Insights into periodization from a 20-years cohort. Front Physiol. 2019;10:363.
15. Solli GS, Tønnessen E, Sandbakk Ø. The training characteristics of the world's most successful female cross-country skier. Front Physiol. 2017;8:1069.
16. Sandbakk Ø, Holmberg HC. Physiological capacity and training routines of elite cross-country skiers: Approaching the upper limits of human endurance. Int J Sports Physiol Perform. 2017;12:1003-11.
17. Tønnessen E, Sylta Ø, Haugen T, Hem E, Svendsen I, Seiler S. The road to gold: Training and peaking characteristics in the year prior to a gold medal endurance performance. PLoS ONE 2014;9:e101796.
18. Sandbakk Ø, Holmberg HC. A reappraisal of success factors for Olympic cross-country skiing. Int J Sports Physiol Perform. 2014 Jan;9(1):117-21.
19. Orie J, Hofman N, de Koning JJ, Foster C. Thirty-eight years of training distribution in Olympic speed skaters. Int J Sports Physiol Perform. 2014;9:93-9.

20. Impellizzeri FM, Marcora SM, Coutts AJ. Internal and external training load: 15 years on. Int J Sports Physiol Perform. 2019;14:270-3.
21. Foster C, Hector LL, Welsh R, Schrager M, Green MA, Snyder AC. Effects of specific versus cross-training on running performance. Eur J Appl Physiol Occup Physiol. 1995;70:367-72.
22. van Ingen Schenau GJ, Cavanagh PR. Power equations in endurance sports. J Biomech. 1990;23:865-81.

Figure 1. Simplified schema on how 'modality' affects different segments in the power flow in endurance performance (adapted from Ingen Schenau & Cavanagh[22]).

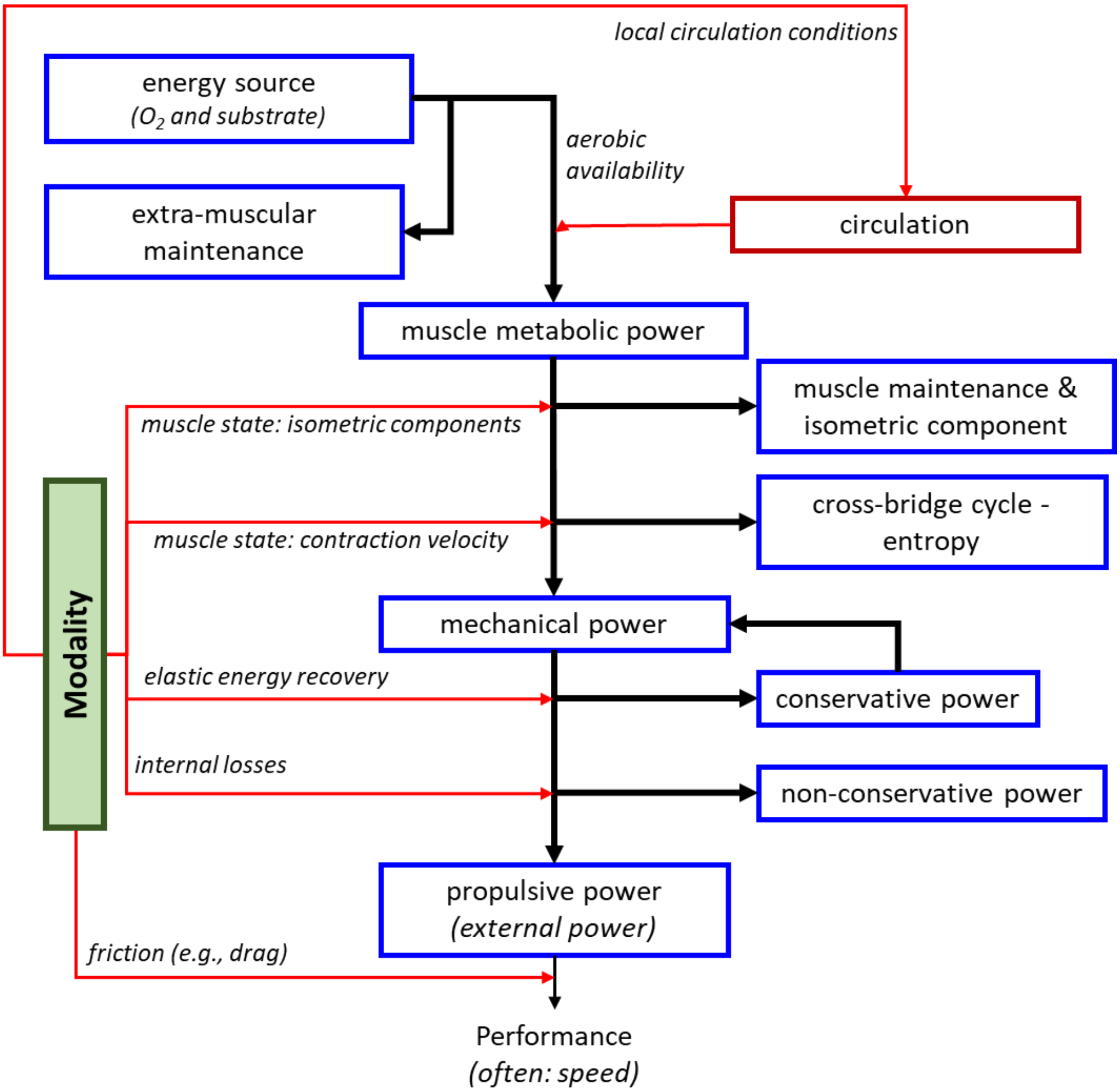

Table 1. Comparison of the main movement constraints and consequences for load tolerance as well as typical duration of low intensity sessions and annual training volumes across sports.

Type of sport	**Movement constraints for the modality**	**Consequences related to load tolerance**	**Typical duration of low intensity sessions (h:min)**	**Annual specific training volume (h)**
Long-distance running	Weight-bearing High impact forces Plyometric Leg-dominant exercise	High injury/overload risk High muscular load Low volume-tolerance	0:45-1:30	5-600
Road cycling	Non-weight-bearing Long contraction time Concentric Leg-dominant exercise	Low injury/overload risk Medium muscular load High volume-tolerance	3:00-5:00	9-1000
Rowing	Non-weight-bearing Medium contraction-time Mainly concentric Whole-body exercise	Medium injury/overload risk High muscular load Medium volume-tolerance	1:00-2:00	6-800
Swimming	Non-weight-bearing Slow contraction-time Mainly concentric Whole-body exercise	Low injury/overload risk Low muscular load High volume-tolerance	1:30-2:30	9-1000
Cross-country skiing	Weight-bearing Different sub-techniques Mainly plyometric Whole-body exercise	Low injury/overload risk Medium muscular load High volume-tolerance	1:30-2:30	500-600
Speed skating	Weight-bearing Slow contraction-time Mainly concentric Leg-dominant exercise	Low injury/overload risk Very high muscular load (occlusion) Low volume-tolerance	0:45-1:15	150-200

Here we consider muscle-tendon injury/overload risks related to long-duration exercise.