Final Research Report
(IBU research grant programme)

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1 Abstract

The overall purpose of this project is to investigate the long-term development of training characteristics in elite junior and senior biathlon athletes. This is investigated through two research projects referred to as Project 1 and Project 2 throughout this report.

Overall objectives:

- Project 1: Investigate the development of physiological, performance, and training characteristics in a highly decorated World-Class female biathlon athlete.
- Project 2: Utilize the framework developed in Project 1 to investigate the development of training characteristics in a larger group of junior and senior biathletes.

1.1 Project 1

The long-term development of performance, physiological, and training characteristics in a world-class female biathlete

Purpose: To investigate the long-term development of performance, physiological, and training characteristics in a world-class female biathlete, with emphasis on differences between junior and senior athlete seasons.

Methods: The participant is a highly decorated female biathlete with 22 (10 gold) medals from international championships and 28 individual World Cup wins. Performance development (age 17-33), physiological tests (age 22-33), and day-to-day physical and shooting training (age 17-33) were analysed. Training data was systemized by endurance (low- [LIT], moderate- [MIT], and high-intensity training [HIT]), exercise mode, and strength training. Shooting training recorded for each session included the number of shots fired during rest, LIT, MIT, HIT, or competitions, and time spent on dry-fire training.

Results: The annual volume of physical training (409 to 792 h·season^{-1}) and number of shots fired (1163 to 17328 shots·season^{-1}) increased from age 17-28 followed by a subsequent reduction in physical training (range 657–763 h·season^{-1}) and shots fired (13275-15355 shots·season^{-1}) during the seasons of peak performance at age 31-33. Maximal oxygen uptake in roller-ski skating increased by 10% (62.9 to 69.2 ml·kg^{-1}·min^{-1}) from age 22-27. The physical training volume was 48% higher (694±60 vs. 468±23 h·season^{-1}), with 175% more shots fired (14537±1109 vs. 5295±3425 shots·season^{-1}) as senior than junior athlete. In the physical training, these differences were mainly explained by higher volumes of LIT (602±56 vs. 392±22 h·season^{-1}) and MIT (34±1 vs. 7±2 h·season^{-1}) but less HIT (27±1 vs. 42±3 h·season^{-1}) as a senior than junior. In line with this, the shooting training as senior included more shots fired both at rest (5035±321 vs. 1197±518 shots·season^{-1}) and during LIT (7440±619 vs. 2663±1975 shots·season^{-1}), while a smaller insignificant difference was observed in the number of shots fired in connection with MIT, HIT, and competitions (2061±174 vs. 1435±893 shots·season^{-1}).

Conclusions: This study provides unique insights into the long-term development of physical and shooting training from junior to senior in a world-class female biathlete. The major differences in training characteristics between junior and senior athlete seasons were higher sport-specific volumes of LIT and MIT, and less HIT. These differences were accompanied by more shooting training, particular at rest, and in connection with LIT.

Keywords: Keywords: endurance training, female athlete, junior athlete, shooting, training quality, XC skiing.

This study is now accepted for publication in Frontiers in Sports and Active Living

1.2 Project 2

Training characteristics in world-class, elite and junior biathletes.

Purposes: 1) to investigate the progression of training characteristics (physical and shooting) during the junior age and 2) to investigate the training and physiological characteristics of world class biathletes.

Methods: In total, 31 senior and junior biathletes from the Norwegain national team (15 female and 16 male) were recruited to the project and have provided their written informed consent to participate. Day-to-day training data from different sources (excel sheets and online training platforms) is exported and systemized into training forms (endurance, strength, and speed), mode (skiing, roller-skiing, running, cycling etc.), and intensity (LIT, MIT and HIT). In addition, shooting-specific training is systemized as shots fired during rest, shots fired during LIT sessions, shots fired during MIT/HIT sessions and competitions, as well as time spent on dry-fire training. Furthermore, data from laboratory tests of performance and physiological profiling will be extracted and systemized. Based on the available data two studies were designed:

1) The progression of training characteristics (physical and shooting) during the junior age (16/17 to 20/21 years old) in biathlon (including data on 25 athletes with training data from this period)

2) The training and physiological characteristics of world class biathletes. Including detailed analyses of the training during one season of world-class performance and the progression of training and physiological capacities towards world-class performance. This study include data on 12 (6 female and 6 male) world-class biathletes with top 10 performance in world-cup or international championships.

Preliminary results available at this stage of the data analysis:

Study 1:
A 14% increase (from 452 to 518 h·season^{-1}) in total endurance training volume was observed from the age of 16/17 to 20/21. This included 14% increase in LIT (411 to 469 h·season^{-1}) and a 67% increase in MIT (15 to 26 h·season^{-1}), while the volume of HIT was reduced by 11% (26 to 22 h·season^{-1}). The volume of sports specific training (skiing or roller skiing in the skating style) increased by 35 % (150 to 202 h·season^{-1}), and the total number of shots fired increased by 49% (from 7450 to 11070 shots·season^{-1}).

Study 2:
Athletes performing at the world-class level showed an average endurance training volume of 597 h·season^{-1}, with a total of 12670 shots·season^{-1} fired. However, a relatively large variation between athletes both in the total endurance training volume (403 to 740) h·season^{-1}) and number of shots fired (9403 to 15 205 shots·season^{-1}) was observed in this cohort of world-class biathletes. Furthermore, 15% lower training volume was observed in female compared to male biathletes (556 h·season^{-1} vs.: 638 h·season^{-1}), while smaller sex differences in the total number of shots fired were observed (12503 shots·season^{-1} vs. 12839 shots·season^{-1} in females and males, respectevly).

More detailed results from both studies will be presented in September.

2 Executive summary

2.1 Project 1

Background

Reaching elite to world-class levels in endurance sports requires a successful long-term development process, and a progressive increase in training volume to ensure sustainability and gradual performance development (Foster et al., 2022). In a recent case study, Schmitt et al. (2021) described the long-term development process of a world-class male biathlete and showed a 32% increase in overall training volume (530 to 700 h·season^{-1}) from the age of 21 to 31. On average, the training consisted of 86% low-intensity training (LIT), 4% moderate-intensity training (MIT), 4% high-intensity training (HIT), and 6% strength training across the annual cycles investigated. In comparison, a 80% increase in training volume (522 to 940 h·season^{-1}) was reported in the most successful female XC skier of all time from the age of 20 to 35 (Solli et al., 2017). Furthermore, a 27% increase in endurance training volume (462 to 635 h·season^{-1}) was observed in a world-class male Nordic combined athlete from the age of 19 to 23 (Rasdal et al., 2018). However, there is still limited knowledge on the progression of endurance training when combined with a mentally challenging task such as shooting in biathlon, and no data on the long-term training characteristics of world-class female biathletes exist.

Therefore, there is a need for better understanding of biathletes' training characteristics, and particularly the challenging balance and progression of physical- and shooting-specific training over time. In addition, previous research on elite endurance athletes has primarily focused on the athletes' senior seasons. In biathlon, there is no existing data on the differences between junior and elite level senior training, where athletes are classified as juniors from the age of 17 until they transition to senior at the age of 23. Therefore, the main aim of this case study was to investigate the long-term development of performance, physiological, and training characteristics in a world-class female biathlete, emphasizing differences between junior and senior athlete seasons.

Methods

The participant in this study is a highly decorated female biathlete with 4 Olympic medals (2 golds), 18 World Championship medals (8 golds), 28 individual World Cup wins, and 4 podiums of the overall International Biathlon Union (IBU) World Cup. The study was approved by the Norwegian Social Science Data Services, and the participant provided written informed consent to participate. To provide a comprehensive understanding and detailed insight into the participant's long-term development process, the study was divided in two parts: 1) a retrospective description of the participant's long-term performance, physiological, and training characteristics across 17 seasons from the age 17 to 33 years (1997-2014); and 2) detailed comparisons between three annual cycles as a junior athlete (18-20 years) and three annual cycles (years of peak performances) as a senior athlete (31-33 years).

Results and discussion

The results showed that the participant followed a long-term progression in the annual volume of physical training (average increase of 40 h·season^{-1}) before achieving her highest training volumes at the age of 27-28. These patterns are similar to those previously described in various world-class endurance athletes (Jones, 2006;Bourgois et al., 2014;Pinot and Grappe, 2015;Solli et al., 2017;Rasdal et al., 2018;Schmitt et al., 2021), further supporting the importance of long-term progression in training volume to reach world-class endurance performances. Interestingly, novel data from this study showed that the progression of physical training was coincided by an average increase of 1200 shots per year, reaching a peak at age 27-28 (17328 shots·season^{-1}). However, a subsequent reduction to ~13275–15355 annual shots during her peak performing seasons (age 31-33) was observed. While no previous data on the progression of shooting training is reported in the literature, the number of shots fired during the participant's seasons of peak performance is in line with the ~12000–15000 annual shots previously reported in a world-class male biathlete (Schmitt et al., 2021). However, a

substantially higher number of shots (~22000 shots·season^{-1}) is reported in Swedish national-team biathletes (Laaksonen et al., 2018).

Furthermore, the participant's physical training volumes were ~30% lower than the ~900 annual training volumes reported in female world-class XC skiers (Sandbakk et al., 2016;Solli et al., 2017). Similar differences have previously been observed between national team XC skiers and biathletes (Myakinchenko et al., 2020;Myakinchenko et al., 2022), and are likely explained by the additional demands for shooting-specific training in biathlon (Laaksonen et al., 2018). Furthermore, the participant performed ~20% higher annual training volumes in the skating style but less strength training (31 vs ~50–90 h·season^{-1}) than previously reported in world-class XC skiers (Sandbakk and Holmberg, 2017;Solli et al., 2017). These findings indicate that biathletes likely compensate for lower physical training volumes than XC skiers by performing more specific training in the skating style. The reason for the lower strength training volume compared to XC skiing can only be speculated, and most likely it reflects the participant's own prioritizations rather than differences in sport-specific demands between biathlon and XC skiing. Taken together, the observed differences in training characteristics between biathlon and XC skiing underpins the complex and demanding nature of biathlon, which requires an adequate load-recovery balance and training quality in both physical and shooting training.

Overall, this case study provides unique insights into the long-term development of physical and shooting training from junior to senior level in a world-class female biathlete. From the age of 17, the participant had a 10-year progression in both the annual volume of physical and shooting training accompanied by development of sport-specific physiological capacities. However, a reduction in both the volume of physical and shooting training was observed during the seasons of peak performance with the intention of increasing training quality. The major differences in training characteristics between junior and senior athlete seasons were higher sport-specific volumes of LIT and MIT, and less HIT particularly during the general preparation period. These differences were accompanied by more shooting-specific training, particular at rest, and in connection with LIT. More data on the training characteristics of larger samples of biathletes at different ages and performance levels is needed to further understand the complexity of biathletes long-term training and performance development.

2.2 Project 2

Background

In 2018, Laaksonen et al., published a comprehensive review on the recent advances and perspectives in the Olympic biathlon. The review revealed increasing scientific interest in biathlon, although most studies investigated the competitive demands and performance determining factors. In contrast, the review only included a brief description on the training characteristics of biathletes based on personal communication with national-team coaches in Sweden. This highlights the need for better scientific understanding of the training characteristics in biathletes. Although much of the available literature on XC skiing may be translated to biathlon, carrying a rifle while skiing and shooting under high physiological and psychological stress provides clear additional demands. It is therefore a need for more knowledge on biathlon-specific training considering both the endurance and shooting-specific training.

To day the available information about biathletes training mainly consist of two case studies Schmitt et al. in 2020 and project 1 of this research report (findings described previously). Case studies like this is a valuable tool providing detailed insight of the training puzzle of world class athletes, generating new hypotheses as well as frameworks for training analysis that can be used in future studies. Still, these studies have clear limitations when it comes to the generalizability of the findings. Therefore, the purpose of this project is to utilize the framework developed in the published case study (Project 1) to 1) investigate the progression of training characteristics (physical and shooting) during junior age (16/17 to 20/21 years old) and 2) investigate the training characterisitcs and physiological characteristics of world class biathletes.

Methods

Methods: In total, 31 senior and junior biathletes from the Norwegain national team (15 female and 16 male) were recruited to the project and have provided their written informed consent to participate in the study. Day-to-day training data from different sources (excel sheets and online platforms) was exported and systemized into training forms (endurance, strength, and speed), mode (skiing, roller-skiing, running, cycling etc.), and intensity (LIT, MIT and HIT). In addition, shooting-specific training is systemized as shots fired during rest, shots fired during LIT sessions, shots fired during MIT/HIT sessions and competitions, as well as time spent on dry-fire training. Furthermore, data from laboratory tests of performance and physiological profiling will be extracted and systemized. Based on the available data two studies were designed: 1) The progression of training characteristics (physical and shooting) during the junior age (16/17 to 20/21 years old) in biathlon (including data on 25 athletes with training data from this period). 2) The training and physiological characteristics of world class biathletes. Including detailed analyses of the training during one season of world-class performance and the progression of training and physiological capacities towards world-class performance. This study include data on 12 (6 female and 6 male) world-class biathletes with top 10 performance in world-cup or international championships.

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Study 2:
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More detailed results and discussion and conlusion will be presented in September (see the updated project schedule in the next section).

3 The research report

3.1 Project 2

A detailed description of the research subject and objectives; the methodology applied; and a detailed presentation of the findings, conclusions, and practical recommendations can be found in the published manuscript. This manuscript will be sent to IBU as soon as it is published (likely during week 24).

3.2 Project 2

All available information about the background, methods and design of this project is included in the executive summary (above).

As highlighted in the interim report, the data collection and systematization of training data have taken more time than scheduled. This is mainly due to changes in design and the fact that more athletes than planned (30 vs. 15-20) have agreed to share their data and participate in the study. This will increase the overall quality of the project but make it more time-consuming to systemize and analyse the data. Therefore, again, we ask IBU for more time to finalize this project, although we will assure to have analyses ready for presentations to IBU in September. Overall, we suggest the following schedule:

Previous schedule for Project 2

- May-October 2022: Recruiting athletes and collecting data from training diaries.
- October-December 2022: Plotting and systematization of training data.
- ~~January-February 2022: Statistical analysis and visualization of data.~~
- ~~March-June 2023: Writing scientific papers.~~
- ~~June-August 2023: Writing research grant reports and finalization the project.~~

Updated schedule for Project 2

- May-October 2022: Recruiting athletes and collecting data from training diaries.
- October-December 2022: Plotting and systematization of training data.
- January-June 2022: Statistical analysis and visualization of data.
- June-September 2023: Writing scientific papers.
- September- 2023: Writing research grant reports and finalization the project.

3.3 Appendix I: Infographic (project 1)

3.4 Appendix II: Financial report

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