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Physiological and biomechanical aspects of rifle carriage during biathlon skiing

Biathlon is an endurance-based winter sport that combines cross-country (XC) skiing with rifle marksmanship. While skiing, biathletes carry the rifle (weighing ≥ 3.5 kg) on their backs. However, research regarding the effects of rifle carriage in biathlon is lacking. Therefore, the aim of this body of work was to investigate how rifle carriage in biathlon affects physiological and biomechanical variables related to biathlon skiing performance, and possible sex differences associated with rifle carriage. Physiological (*Study I*) and kinematical (*Study III*) effects of rifle carriage were tested in a laboratory using treadmill roller-skiing, whereas the effects of rifle carriage on gear distribution were tested in the field on snow (*Study IV*). In addition, the effects of supplementary rifle-carriage training on physiological variables and skiing performance were investigated (*Study II*).

The results of this thesis show that rifle carriage affects both physiological and biomechanical variables during biathlon skiing. From a physiological perspective, skiing with the rifle (WR) increased respiratory variables (oxygen uptake, ventilation rate and carbon dioxide production) and blood lactate concentration (BLa) at workloads around or above the lactate threshold during submaximal skiing, while the speed at 4 mmol of BLa ($speed_{@4mmol}$) decreased compared to skiing without the rifle (NR) (*Study I*). During maximal treadmill roller-skiing the anaerobic metabolic rate (MR_{an}) decreased when skiing WR, and MR_{an} together with $speed_{@4mmol}$ explained ~ 80% of the variation in time trial (TT) performance WR (*Study I*). Rifle carriage also impaired TT performance during both treadmill roller-skiing in the laboratory (*Study I*) and on-snow skiing in the field (*Study IV*). From a biomechanical perspective, skiing WR decreased flexion/extension range of motion (ROM) in the shoulder and thorax, while abduction/adduction and internal/external rotation ROM in the shoulder and thorax increased compared to NR (*Study III*). Rifle carriage also decreased the maximal height of the shoulders during skiing (i.e., exhibiting a lower body position), which was related to a more forward tilt of the thorax compared

to skiing NR (*Study III*). During the on-snow TT, skiing WR increased the use of gear 2, while the distance and time spent in gear 3 was decreased (*Study IV*). Although the relative mass of the rifle was greater for the women compared to the men (*Study I–IV*), the physiological, performance and biomechanical responses to rifle carriage were similar for both sexes. The only exception was a larger decrease in flexion/extension ROM in the thorax during skiing WR for the women compared to the men (*Study III*). During the training intervention, only ~ 10% of the endurance-based training was performed WR for the control group. Compared to the control group, one additional training session per week (~ 2 h·week^{-1}) WR over a 16-week period did not affect physiological variables or improve roller-skiing performance (*Study II*).

This body of work showed that rifle carriage affects physiological, biomechanical and performance aspects of biathlon skiing, and that a relatively low amount of the training is performed WR. This thesis contributes new knowledge of the unique demands of biathlon skiing, which can inform development of sport-specific training. To improve biathlon skiing performance, training WR may be individualized to each athlete, with specific focus on training intensities and technique development when skiing with the rifle.

Keywords: 3D-measurement, anaerobic energy contribution, cross-country skiing, kinematics, lactate threshold, load carriage, oxygen uptake, performance, sex differences, sub-techniques, training