Maximal aerobic capacity in the Winter Olympic endurance disciplines: current Olympic medal benchmarks

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Introduction

Maximal oxygen uptake (VO$_2$ max) is a key performance parameter in winter Olympic endurance sports. Since 1990, the Norwegian Olympic Training Center has served as a standard testing facility for a large number of athletes in contention for national team representation, including multiple medal winners in cross-country skiing (XC), biathlon, Nordic combined and speed-skating. There is little current data available regarding aerobic capacity demands associated with international events in these events. Therefore, the purpose of this study was to establish current Olympic medal benchmarks for maximal aerobic capacity in these events.

Methods

We identified 145 male and female athletes who either won medals or participated in winter Olympic Games or World Championships in the period 1990-2013. In total, the identified athletes had won 76 Olympic (32-21-23) and 209 World Championship medals (86-62-61) in the time period 1990-2013. This accounted for 32 % of all individual medals in cross-country skiing, 20 % in biathlon, 19 % in Nordic combined and 7 % in all-round speed-skating. All identified athletes tested VO$_2$ max at the Norwegian Olympic Training Center ≥ one time within the same year of the actual competition. The testing procedures were consistent throughout the entire period, making all data comparable.

Results

For the medal winning athletes, the following relative VO$_2$ max values were observed: XC distance (72.6: 76.2-69.0) ml·min$^{-1}$·kg$^{-1}$ (n=10), XC sprint (68.6: 73.2-64.0) (n=5), biathlon (65.8: 72.1-59.6) (n=7). VO$_2$ max relative to bodyweight was significantly higher by 2-4 ml · min$^{-1}$·kg$^{-1}$ among medalists compared with non-medalists in distance XC skiing (females), biathlon (females) and Nordic combined disciplines. Current upper limits for maximal oxygen consumption measured in these exceptional male performers now exceed 7 L·min$^{-1}$ and/or 90 ml · min$^{-1}$·kg$^{-1}$. Female performers at or approaching 80 ml · min$^{-1}$·kg$^{-1}$ and just under 9 L·min$^{-1}$ have been measured among XC skiing medalists. Aerobic capacity in speed skaters is probably best expressed in absolute terms and male medal winners average 6.0 L·min$^{-1}$.

Discussion

Elite male and female performers in winter endurance sports, particularly XC, have become heavier due to greater muscle mass, while demonstrating a concurrent increase in central capacity, such that absolute oxygen consumption has increased substantially (~1 L·min$^{-1}$) since the seminal measurements published by Saltin & Åstrand in 1967. Even among national team athletes, higher VO$_2$ max tends to distinguish medalists from non-medalists. While XC skiing is a one-dimensional discipline, both Nordic combined (skiing and ski jump) and Biathlon (skiing and shooting) have 2 performance components that must be both selected for and trained for. The lower aerobic capacity of the best performers in these disciplines compared to XC can be seen in light of these demands. For speed skaters, aerobic capacity may be best expressed in terms of absolute capacity, where medal winners often exceed 6 L·min$^{-1}$ among men.

For the female medalists, the following VO$_2$ max values were observed: XC distance (72.6: 76.2-69.0) ml·min$^{-1}$·kg$^{-1}$ (n=10), XC sprint (68.6: 73.2-64.0) (n=5), biathlon (65.8: 72.1-59.6) (n=7). VO$_2$ max relative to bodyweight was significantly higher by 2-4 ml · min$^{-1}$·kg$^{-1}$ among medalists compared with non-medalists in distance XC skiing (females), biathlon (females) and Nordic combined disciplines. Current upper limits for maximal oxygen consumption measured in these exceptional male performers now exceed 7 L·min$^{-1}$ and/or 90 ml · min$^{-1}$·kg$^{-1}$. Female performers at or approaching 80 ml · min$^{-1}$·kg$^{-1}$ and just under 9 L·min$^{-1}$ have been measured among XC skiing medalists. Aerobic capacity in speed skaters is probably best expressed in absolute terms and male medal winners average 6.0 L·min$^{-1}$.

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Figure 1. 95 % confidence intervals for relative VO$_2$ max across winter sport disciplines. Group means with the same letters are not statistically different from each other.