Practical and scientific experiences from optimizing the sport-specific development of endurance transfer athletes

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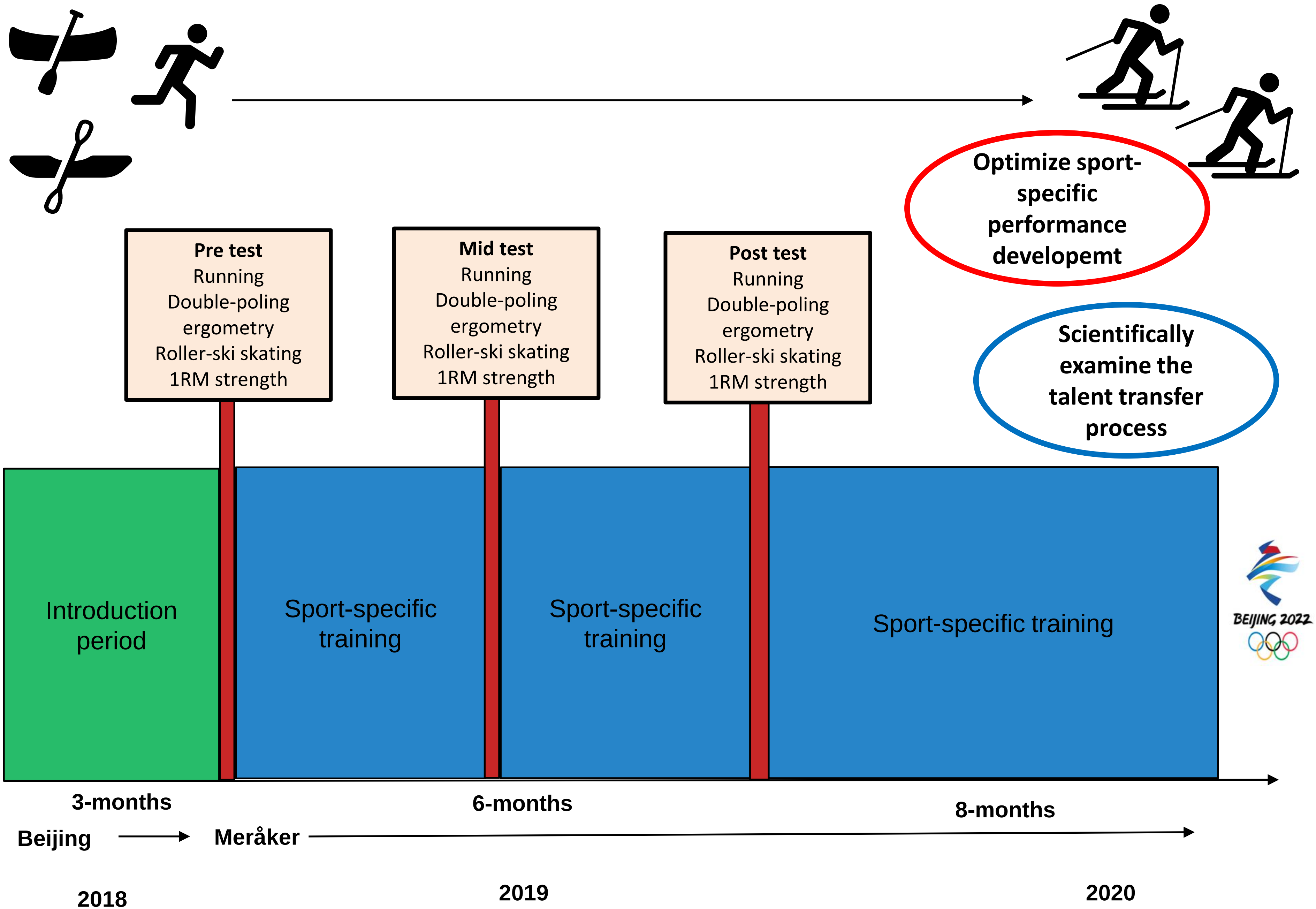
Background

- Beijing Olympic Winter Games 2022
- Meråker High School in mid-Norway
- Team China Meråker (2018-2020)
- Talent transfer program
- Combining research and practice in optimizing athletes sport-specific development


Pre test
Running
Double-poling
ergometry
Roller-ski skating
1RM strength
Mid test
Running
Double-poling
ergometry
Roller-ski skating
1RM strength
Post test
Running
Double-poling
ergometry
Roller-ski skating
1RM strength
Optimize sport-specific performance developemt
Scientifically examine the talent transfer process
Introduction period
Sport-specific training
Sport-specific training
Sport-specific training
BEIJING 2022
3-months
6-months
8-months
Beijing
Meråker
2018
2019
2020

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Development of Performance, Physiological and Technical Capacities During a Six-Month Cross-Country Skiing Talent Transfer Program in Endurance Athletes

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Purpose: To examine the development of performance, physiological and technical capacities as well as the effect of sport background among runners, kayakers and rowers when transferred to cross-country (XC) skiing over a 6-month training period.

Methods: Twenty-four endurance athletes (15 runners and 9 rowers/kayakers; 15 men and 9 women) were tested for performance, physiological and technical capacities during treadmill running and roller-ski skating, double-poling ergometry, as well as upper-body, one-repetition maximum-strength (1 RM) at baseline (pre) after three (mid) and 6-months (post) of XC ski-specific training.

Results: Peak treadmill speed when roller-ski skating improved significantly (13%, $P < 0.01$) from pre-post, with a larger improvement in runners than in kayakers/rowers (16 vs. 9%, $P < 0.05$), whereas peak speed in running was unchanged. Average power output during 5-min and 30-s ergometer double-poling tests improved by 8% and 5% (both $P < 0.01$), with improvement found only in runners on the 30-s test (8 vs. −2% in kayakers/rowers, $P < 0.01$). Peak oxygen uptake (VO_{2peak}) in running and double-poling ergometry did not improve, whereas VO_{2peak} in roller-ski skating improved by 5% in runners ($P < 0.05$). Submaximal gross efficiency increased by 0.6%-point and cycle length by 13%, whereas 1 RM in seated pull-down and triceps press increased by 12 and 11%, respectively (all $P < 0.05$).

Conclusion: Six-months of XC ski-specific training induced large improvements in sport-specific performance which were associated with better skiing efficiency, longer cycle length, and greater 1RM upper-body strength in a group of endurance athletes transferring to XC skiing. Furthermore, larger sport-specific development was found in runners compared to kayakers/rowers.

Keywords: aerobic capacity, cycle length, gross efficiency, endurance training, strength training, Olympics

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Comparison of High- vs. Low-Responders Following a 6-Month XC Ski-Specific Training Period: A Multidisciplinary Approach

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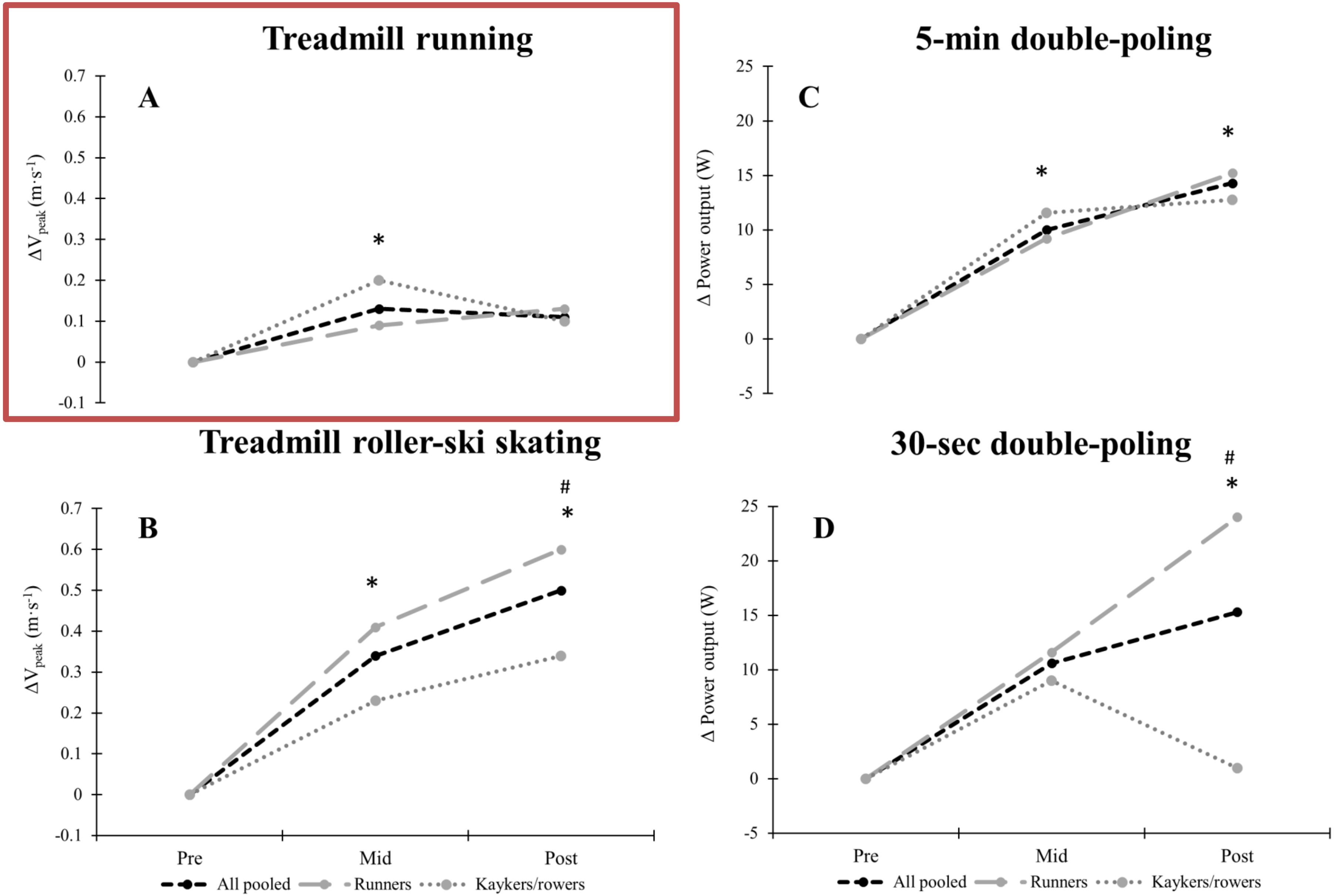
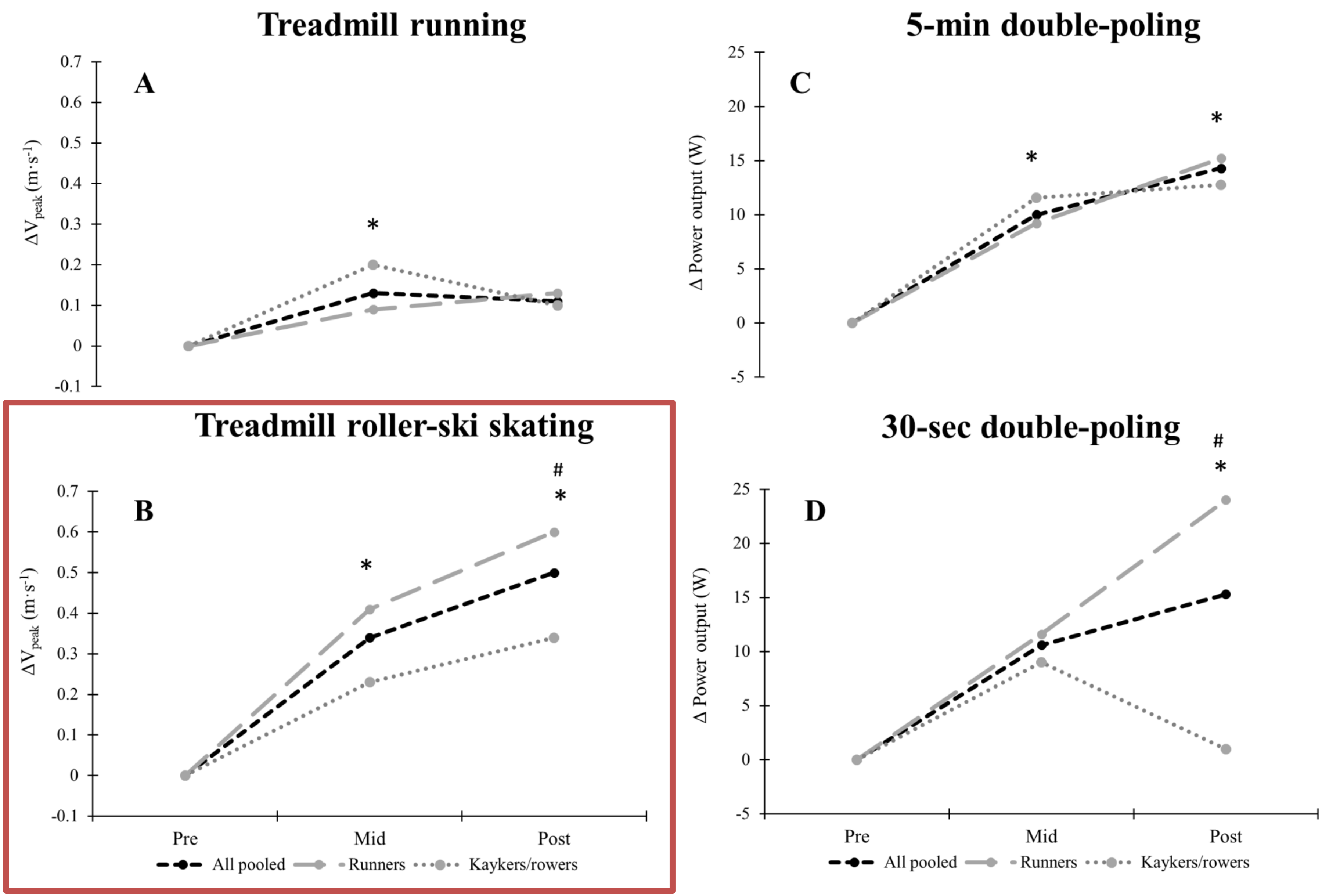
Individual training responses among endurance athletes are determined by a complex interplay between training load, recovery and genetic influence. The present study used a multidisciplinary approach to compare high- and low-responders following a 6-month training period in endurance athletes transferring to cross-country (XC) skiing. Twenty-three endurance-trained athletes (14 runners and 9 rowers/kayakers; 14 men and 9 women) were classified as high ($n = 9$) or low-responders ($n = 11$) based on pre- to post changes in treadmill running, roller-ski skating and double-poling ergometry performances following 6-months of standardized XC ski-specific training. Physiological and technical capacities during these same modes were monitored pre and post. In addition, training volume, intensity, mode and session rating of perceived exertion (sRPE) training load were quantified daily. Finally, qualitative interviews of the athlete's personal coaches were performed after the intervention. There were no differences between groups with respect to physiological baseline characteristics. High-responders improved maximum oxygen uptake (VO_{2max}) in treadmill running (5.5 ± 7.0% change from pre- to post) as well as peak oxygen uptake (VO_{2peak}; 7.3 ± 7.0%) and power output at 4 $mmol{\cdot}L^{-1}$ (37.7 ± 28.2%) treadmill roller-ski skating which differed from a corresponding non-significant change in low-responders (−1.2 ± 3.6%, −2.7 ± 3.7% and 8.2 ± 12.5%; all $P \leq 0.05$). VO_{2peak} in double-poling ergometry did not change in any group, whereas gross efficiency and cycle length in roller-ski skating improved in both groups. High-responders performed greater training loads (weekly load: 3825 ± 1013 vs. 3228 ±.748 and load/volume ratio: 4.9 ± 0.6 vs. 4.2 ± 0.5; both $P \leq 0.05$) and had lower incident of injury/illness (5 ± 3 vs. 10 ± 5 days; $P = 0.07$). Their coaches highlighted high motivation to train and compete, together with the ability to build a strong coach-athlete relationship, to separate high- from low-responders. In conclusion, high-responders to 6-months of standardized XC ski-specific training demonstrates greater improvement in maximal/peak aerobic capacity, which was coincided by higher training loads, greater

- Twenty-four talent transfer athletes (15 runners and 9 kayakers/rowers)
- Performance, physiological and technical capacities
- Training characteristics and training load
- Qualitative assessments of their Norwegian coaches

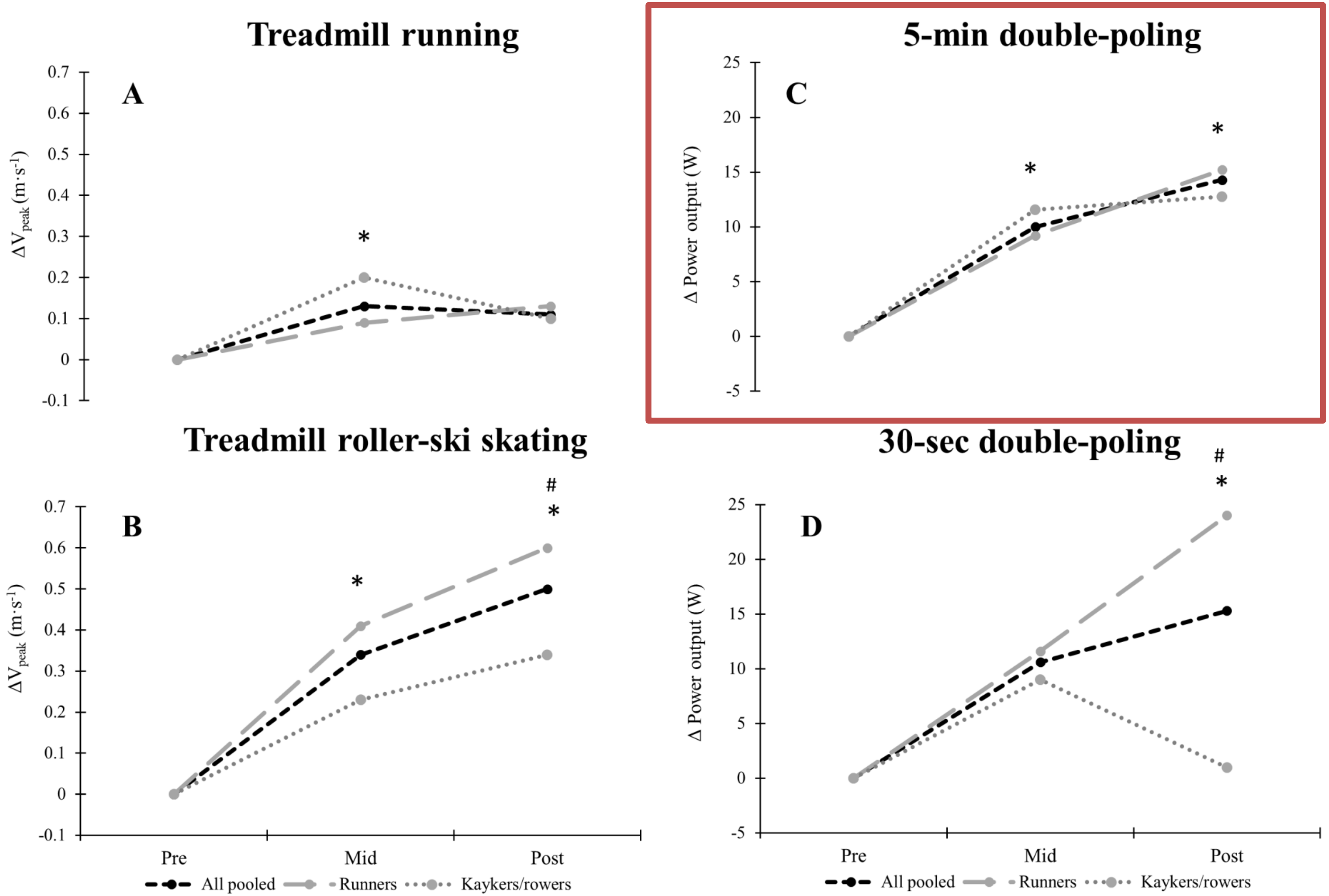
General mode

Sport-specific mode

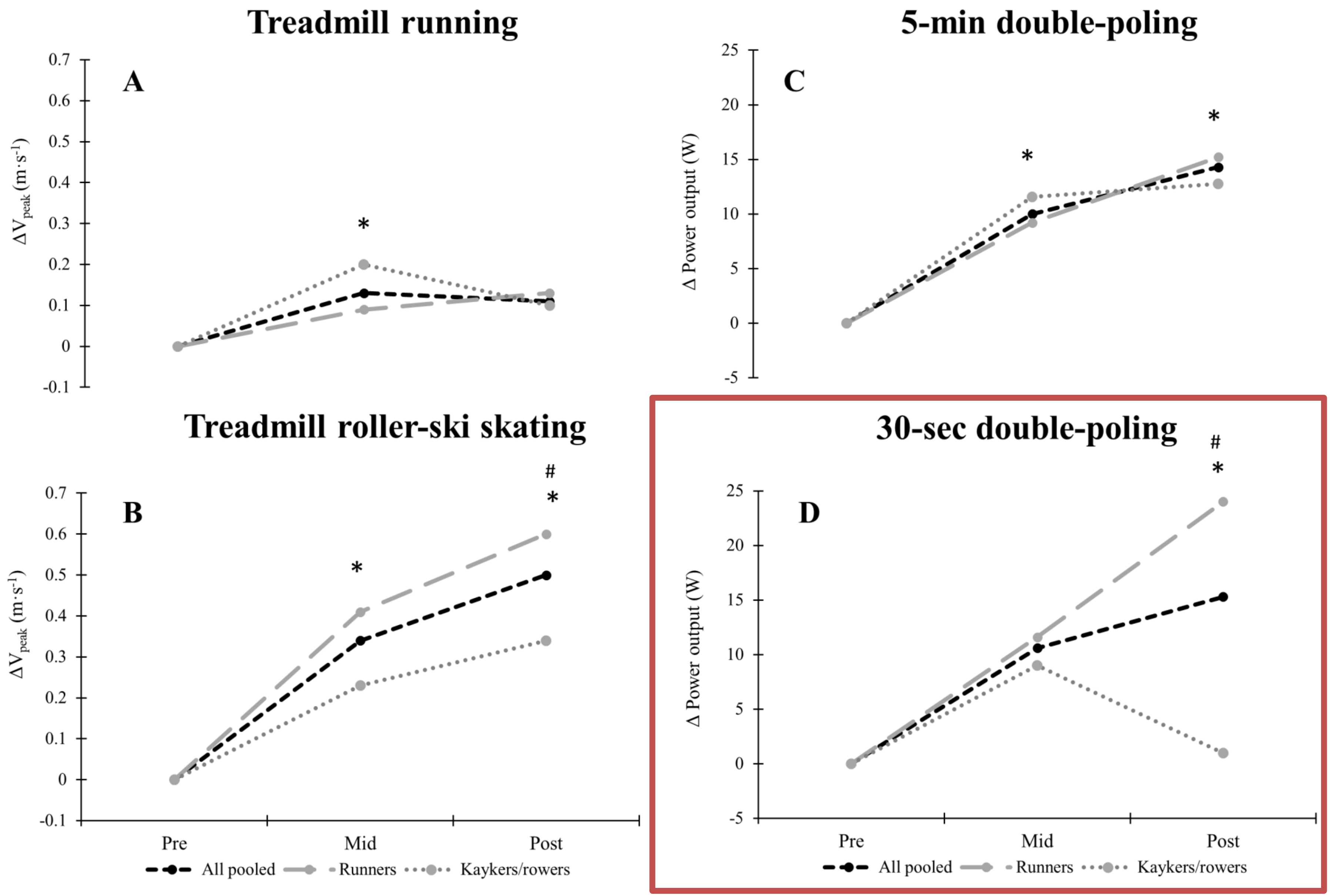

Treadmill running
A
ΔVpeak (m·s-1)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
*
5-min double-poling
C
Δ Power output (W)
25
20
15
10
5
0
-5
*
*
Treadmill roller-ski skating
B
ΔVpeak (m·s-1)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
*
#
*
Pre
Mid
Post
All pooled
Runners
Kaykers/rowers
30-sec double-poling
D
Δ Power output (W)
25
20
15
10
5
0
-5
#
*
Pre
Mid
Post
All pooled
Runners
Kaykers/rowers



Treadmill running
A
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
ΔVpeak (m·s-1)
*
5-min double-poling
C
25
20
15
10
5
0
-5
Δ Power output (W)
*
*
Treadmill roller-ski skating
B
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
ΔVpeak (m·s-1)
*
#
*
Pre
Mid
Post
All pooled
Runners
Kaykers/rowers
30-sec double-poling
D
25
20
15
10
5
0
-5
Δ Power output (W)
#
*
Pre
Mid
Post
All pooled
Runners
Kaykers/rowers



Treadmill running
A
ΔVpeak (m·s-1)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
*
5-min double-poling
C
Δ Power output (W)
25
20
15
10
5
0
-5
*
*
Treadmill roller-ski skating
B
ΔVpeak (m·s-1)
*
#
*
Pre
Mid
Post
All pooled
Runners
Kaykers/rowers
30-sec double-poling
D
Δ Power output (W)
#
*
Pre
Mid
Post
All pooled
Runners
Kaykers/rowers

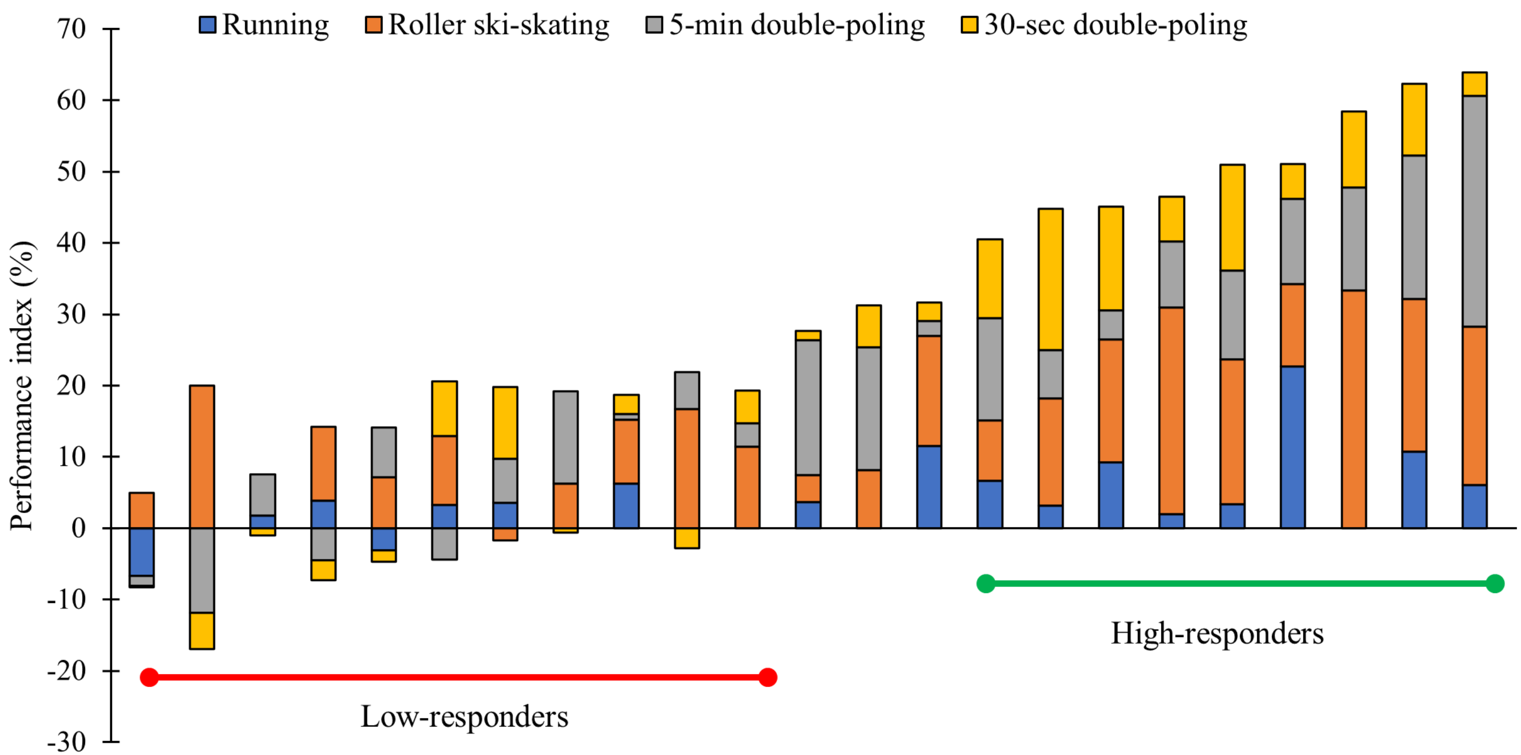


Treadmill running
A
ΔVpeak (m·s-1)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
*
5-min double-poling
C
Δ Power output (W)
25
20
15
10
5
0
-5
*
*
Treadmill roller-ski skating
B
ΔVpeak (m·s-1)
#
*
*
Pre
Mid
Post
All pooled
Runners
Kaykers/rowers
30-sec double-poling
D
Δ Power output (W)
#
*
Pre
Mid
Post
All pooled
Runners
Kaykers/rowers

TABLE 3 | Performance, physiological and technical capacities (mean ± SD) in treadmill roller-ski skating, double-poling ergometry and treadmill running as well as upper-body 1RM strength in 24 endurance transfer athletes during pre-, mid- and post-tests of a 6-month XC ski-specific training period.

	Pre-test	Mid-test	Post-test	Pre-post
Body mass (kg)	65.4 ± 9.9	65.4 ± 9.3	65.6 ± 9.5	0.02
TREADMILL ROLLER-SKI SKATING				**ES[a]**
V_{peak} ($m \cdot s^{-1}$)	3.85 ± 0.26	4.19 ± 0.35**	4.35 ± 0.37**	1.56
Power V_{peak} (W)	241 ± 45	261 ± 46**	270 ± 47**	1.54
VO_{2peak} ($L \cdot min^{-1}$)	3.93 ± 0.75	4.07 ± 0.73[#]	4.02 ± 0.73	0.12
VO_{2peak} ($mL \cdot min^{-1} \cdot kg^{-1}$)	60.0 ± 6.1	62.1 ± 7.1[#]	61.3 ± 7.2	0.19
Maximum respiratory exchange ratio	1.09 ± 0.04	1.09 ± 0.04	1.11 ± 0.05	0.44
Maximum blood lactate ($mmol \cdot L^{-1}$)	8.6 ± 2.1	9.8 ± 1.8	10.0 ± 2.2*	0.65
Peak heart rate ($beats \cdot min^{-1}$)	189 ± 9	192 ± 8**	191 ± 7*	0.24
Peak RPE (1–10)	6.5 ± 1.4	8.5 ± 1.5**	8.7 ± 1.5**	1.41
Submaximal power 4 $mmol \cdot L^{-1}$ (W)	140 ± 36	138 ± 32	165 ± 35**	0.70
Submaximal O_2-cost ($L \cdot min^{-1}$)	2.86 ± 0.44	2.83 ± 0.41	2.74 ± 0.41*	0.28
Submaximal O_2-cost ($mL \cdot min^{-1} \cdot kg^{-1}$)	43.8 ± 4.0	43.3 ± 3.1	42.0 ± 3.0*	0.51
Submaximal respiratory exchange ratio	0.95 ± 0.05	0.95 ± 0.04	0.92 ± 0.04*	0.22
Submaximal heart rate ($beats \cdot min^{-1}$)	164 ± 12	163 ± 13	157 ± 11*	0.61
Submaximal blood lactate ($mmol \cdot L^{-1}$)	3.4 ± 1.0	3.2 ± 0.9	2.3 ± 0.8**	1.21
Submaximal RPE (1–10)	3.4 ± 0.7	3.3 ± 0.8	2.9 ± 0.8	0.66
Submaximal gross efficiency (%)	12.8 ± 1.1	12.8 ± 1.0	13.4 ± 0.9**	0.59
Submaximal cycle length (m)	5.10 ± 0.40	5.69 ± 0.48**	5.76 ± 0.51**	1.44
Submaximal cycle rate (Hz)	0.49 ± 0.04	0.44 ± 0.04**	0.44 ± 0.04**	1.25
DOUBLE-POLING ERGOMETRY				
Power output 5-min performance test (W)	196 ± 43	207 ± 43**	211 ± 45**	0.34
Peak power 5-min performance test (W)	265 ± 59	276 ± 59	273 ± 56	0.14
Power output 30-s Wingate test (W)	332 ± 86	342 ± 84	394 ± 100*	0.66
Peak power output 30-s Wingate test (W)	394 ± 100	434 ± 147	425 ± 127**	0.27
VO_{2peak} ($L \cdot min^{-1}$)	3.76 ± 0.83	3.83 ± 0.78	3.86 ± 0.76	0.12
VO_{2peak} ($mL \cdot min^{-1} \cdot kg^{-1}$)	57.3 ± 8.3	58.3 ± 8.5	58.7 ± 7.2	0.18
Maximum respiratory exchange ratio	1.03 ± 0.05	1.05 ± 0.04	1.03 ± 0.04	0.00
Maximum blood lactate ($mmol \cdot L^{-1}$)	12.5 ± 1.9	13.0 ± 2.6	12.7 ± 2.5	0.09
Peak heart rate ($beats \cdot min^{-1}$)	181 ± 10	183 ± 8	181 ± 7	0.00
Peak RPE (1–10)	7.7 ± 1.8	8.4 ± 1.5	8.6 ± 0.9[#]	0.63
TREADMILL RUNNING				
V_{peak} ($m \cdot s^{-1}$)	4.05 ± 0.43	4.18 ± 0.37*	4.16 ± 0.35	0.28
VO_{2max} ($L \cdot min^{-1}$)	4.22 ± 0.84	4.34 ± 0.84[#]	4.26 ± 0.76	0.05
VO_{2max} ($mL \cdot min^{-1} \cdot kg^{-1}$)	64.4 ± 7.5	66.3 ± 7.4[#]	65.0 ± 7.3	0.08
Maximum respiratory exchange ratio	1.13 ± 0.04	1.15 ± 0.03	1.13 ± 0.04	0.00
Maximum blood lactate ($mmol \cdot L^{-1}$)	10.2 ± 2.7	11.2 ± 1.6	11.4 ± 1.9	0.51
Maximum heart rate ($beats \cdot min^{-1}$)	193 ± 9	194 ± 9	194 ± 8	0.12
Maximum RPE (1–10)	8.0 ± 1.7	8.9 ± 1.2	8.7 ± 1.2	0.47
Submaximal speed 4 $mmol \cdot L^{-1}$ ($m \cdot s^{-1}$)	2.68 ± 0.29	2.57 ± 0.25[#]	2.70 ± 0.28	0.07
1RM UPPER-BODY STRENGTH				
Seated pull-down exercise (kg)	57.8 ± 11.1	62.3 ± 12.0**	64.2 ± 11.7**	0.56
Triceps-press exercise (kg)	60.5 ± 11.4	65.4 ± 11.3**	66.6 ± 11.5**	0.53

*V_{peak}, peak treadmill speed; VO_{2peak}, peak oxygen uptake; RPE, rating of perceived exhaustion (1–10); VO_{2max}, maximum oxygen uptake. *Significant difference from pre-test (**$P < 0.01$; *$P < 0.05$). [#]Tendency toward significant difference from pre-test ($P = 0.05$–0.1). [a]ES of pre-post changes calculated according to Cohens d.*



Running
Roller ski-skating
5-min double-poling
30-sec double-poling
Performance index (%)
70
60
50
40
30
20
10
0
-10
-20
-30
High-responders
Low-responders

TABLE 1 | Performance, physiological and technical capacities (mean ± SD) in treadmill running, treadmill roller-ski skating and double-poling ergometry as well as upper-body 1RM strength in high and low-responders at pre and post of a 6-month XC ski-specific training period.

	High-responders		Low-responders		Pre-post
	Pre	Post	Pre	Post	ES[a]
Treadmill running					
V_{peak} ($m \cdot s^{-1}$)	4.15 ± 0.50	$4.42 \pm 0.33^{**}$	3.98 ± 0.33	$4.00 \pm 0.28^{\#}$	1.36
VO_{2max} ($L \cdot min^{-1}$)	4.32 ± 0.54	$4.52 \pm 0.50^{*}$	4.34 ± 1.04	$4.25 \pm 0.90^{\#}$	1.20
VO_{2max} ($mL \cdot min^{-1} \cdot kg^{-1}$)	67.0 ± 7.6	$70.4 \pm 4.8^{*}$	63.0 ± 6.6	$62.2 \pm 6.5^{\#}$	1.23
Submaximal speed 4 $mmol \cdot L^{-1}$ ($m \cdot s^{-1}$)	2.77 ± 0.24	2.84 ± 0.23	2.57 ± 0.27	2.56 ± 0.26	0.54
Treadmill roller-ski skating					
V_{peak} ($m \cdot s^{-1}$)	3.88 ± 0.21	$4.65 \pm 0.28^{***}$	3.91 ± 0.28	$4.23 \pm 0.27^{**\#}$	1.71
Power VO_{2peak} (W)	238 ± 24	$283 \pm 22^{**}$	255 ± 56	$267 \pm 50^{**\#}$	1.13
VO_{2peak} ($L \cdot min^{-1}$)	4.00 ± 0.39	$4.26 \pm 0.41^{**}$	4.13 ± 0.88	$4.01 \pm 0.87^{**\#}$	1.84
VO_{2peak} ($mL \cdot min^{-1} \cdot kg^{-1}$)	62.0 ± 5.8	$66.3 \pm 5.8^{**}$	60.2 ± 5.7	$58.5 \pm 5.6^{**\#}$	1.80
Submaximal power 4 $mmol \cdot L^{-1}$ (W)	129 ± 30	$173 \pm 30^{**}$	154 ± 37	$165 \pm 41^{*\#}$	1.53
Submaximal O_2-cost ($L \cdot min^{-1}$)	2.87 ± 0.19	$2.74 \pm 0.19^{**}$	2.95 ± 0.57	$2.82 \pm 0.53^{**}$	0.06
Submaximal respiratory exchange ratio	0.95 ± 0.05	$0.90 \pm 0.03^{**}$	0.95 ± 0.04	$0.94 \pm 0.05^{\#}$	0.97
Submaximal heart rate ($beats \cdot min^{-1}$)	166 ± 12	$153 \pm 9^{**}$	161 ± 10	$159 \pm 11^{\#}$	1.25
Submaximal blood lactate ($mmol \cdot L^{-1}$)	3.7 ± 1.1	$2.1 \pm 0.7^{**}$	3.2 ± 0.9	$2.5 \pm 0.7^{**}$	0.83
Submaximal RPE (1-10)	3.1 ± 0.6	$2.7 \pm 0.7^{**}$	3.5 ± 0.9	3.2 ± 0.5	0.00
Submaximal gross efficiency (%)	12.5 ± 1.1	$13.3 \pm 0.6^{**}$	13.0 ± 1.0	$13.5 \pm 0.8^{**}$	0.23
Submaximal cycle length (m)	5.32 ± 0.34	$6.05 \pm 0.47^{**}$	$4.97 \pm 0.34^{\dagger}$	$5.65 \pm 0.37^{**}$	0.17
Submaximal cycle rate (Hz)	0.47 ± 0.03	$0.42 \pm 0.03^{**}$	0.51 ± 0.03	$0.44 \pm 0.03^{**}$	0.12
Double-poling ergometry					
Power output 5-min test (W)	193 ± 22	$219 \pm 20^{**}$	208 ± 53	$212 \pm 40^{\#}$	1.58
Peak power output 5-min test (W)	274 ± 40	292 ± 40	274 ± 70	266 ± 67	0.36
Power output 30-sec test (W)	333 ± 35	$368 \pm 47^{**}$	352 ± 110	$353 \pm 105^{\#}$	2.13
Peak power output 30-sec test (W)	394 ± 43	$441 \pm 56^{**}$	416 ± 131	443 ± 167	0.47
VO_{2peak} ($L \cdot min^{-1}$)	3.90 ± 0.40	4.05 ± 0.25	3.85 ± 1.06	3.90 ± 0.98	0.45
VO_{2peak} ($mL \cdot min^{-1} \cdot kg^{-1}$)	60.7 ± 7.3	63.1 ± 5.6	55.6 ± 8.0	56.5 ± 6.1	0.37
1RM upper-body strength					
Seated pull-down exercise (kg)	57.0 ± 5.7	$65.9 \pm 8.3^{**}$	60.5 ± 14.4	$65.5 \pm 13.6^{**}$	0.84
Triceps-press exercise (kg)	61.3 ± 6.9	$68.8 \pm 6.0^{**}$	63.0 ± 13.1	$67.0 \pm 14.1^{**}$	0.78

V_{peak}, peak treadmill speed; VO_{2max}, maximum oxygen uptake; VO_{2peak}, peak oxygen uptake; RPE, rating of perceived exertion (1–10).

[†]Significant difference between groups at baseline (pre).

**Significant pre- to post change within groups (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$).*

[#]Significant difference in pre- to post change between groups ($P < 0.05$).

[a]ES of pre- to post change between groups calculated according to Cohens d.

TABLE 2 | Training characteristics (mean ± SD) in high- and low-responders during a 6-month XC ski-specific training period.

	High-responders	Low-responders
Total training		
Total (h)	363 ± 11	344 ± 23*
Total (sessions)	311 ± 15	290 ± 30
Rest (days)	22 ± 1	22 ± 2
Injury/illness (days)	5 ± 3	10 ± 5
Training forms		
Endurance (h)	271 ± 6	259 ± 14*
Strength (h)	38 ± 1	37 ± 2
Speed (h)	14 ± 1	14 ± 1
XC skiing drills (h)	40 ± 6	34 ± 9
Exercise modes		
Running (h)	85 ± 3	81 ± 5*
Roller-ski skating (h)	11 ± 1	11 ± 2
Roller-ski classic (h)	8 ± 1	8 ± 2
Ski skating (h)	111 ± 3	108 ± 5
Ski classic (h)	70 ± 1	66 ± 7*
Endurance training time		
LIT (h)	232 ± 6	223 ± 12*
MIT (h)	13 ± 1	12 ± 1*
HIT (h)	26 ± 1	24 ± 2*
LIT/MIT/HIT (%)	85/5/10	86/5/9
Training load		
Load (sRPE/wk)	3825 ± 1013	3228 ± 748*
Load/volume ratio (sRPE/h)	4.9 ± 0.6	4.2 ± 0.5*

LIT, low-intensity training; MIT, moderate-intensity training; HIT, high-intensity training.
**Significant difference between groups (*$P < 0.05$).*

TABLE 4 | Multidisciplinary overview of health, psychological and sociological related factors differentiating high- from low-responders following 6-months of XC ski-specific training in a group of endurance transfer athletes including direct verbatim quotes from the athlete's personal coaches.

High-responders	Low-responders	Verbatim quotes from coaches
Health • ↓↓↓↓ Incidents of injury and/or illness • Good health*	**Health** • ↑↑↑↑ Incidents of injury and/or illness days • Athletes with signs of overtraining*	*"In total, there were few cases of injury or illness among high-responders, which might have been crucial for their better adaptations and development."* *"High responders showed continuity in their work, maintained good health and found the optimal balance between load and recovery together with their personal coach."*
Psychological* • Highly motivated • Strong passion for skiing • Enjoyment during and between training sessions	**Psychological*** • Less motivation • Less passion for skiing • Less enjoyment during and between training sessions	*"Motivation, enjoyment and passion, together with desire and curiosity to learn and improve… These are clear characteristics of the highest responding athletes… if you are not happy in life and with what you are doing, then it doesn't matter what you do and if you have the best coaches and the best training program… it doesn't matter…"* *"The best responding athletes gave things several tries and did not give up…they responded constructively to feedback, and showed an inner drive and interest to develop which can be hard to maintain in such a demanding project"*
Sociological* • State of well-being individually and/or in the training group • Positive coach-athlete relationship	**Sociological*** • Less well-being individually and/or in the training group • Less positive coach-athlete relationship • More homesickness	*"strong well-being in the process of transferring to a new sport and to a new country with different culture were important and homesickness were definitely more present among those athletes with a low training response"* *"high responding athletes communicated well with their coach and by that developed some level of independency/trust in their own work during the training period"* *"It seems like the boys liked better staying in Norway. They were tightly connected, had fun and spent awesome time together both during and between sessions"*

↑↓ Effect size of difference between groups (↑/↓ = trivial, ↑↑/↓↓ = small, ↑↑↑/↓↓↓ = moderate, ↑↑↑↑/↓↓↓↓ = large).
**Based on qualitative assessments of the athlete's personal coaches.*

Practical and scientific experiences

- Systematic training process
- Detailed monitoring of adaptations and performance development
- Multidisciplinary approach to optimize all training and recovery routines
- Provided simultaneously a unique opportunity to scientifically examine a talent transfer process
- Describing the factors underlying successful talent transfer in XC skiing.

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