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A 11-day compressed overload and taper induces larger physiological improvements than a normal taper in elite cyclists

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Endurance athletes usually achieve performance peaking with 2-4 weeks of overload training followed by 1-3 weeks of tapering. With a tight competition schedule, this may not be appropriate. Thus, the aim of this study was to compare the effect of a compressed variant of the recommended overload and tapering approach (EXP; n = 9, VO_{2peak} = 77 ± 5 $mL·min^{-1}·kg^{-1}$) with a 11-day traditional taper that maintained the usual frequency of high-intensity aerobic interval training (HIT) and reduced the duration of training at lower exercise intensity (TRAD, n = 8, VO_{2peak} = 74 ± 4 $mL·min^{-1}·kg^{-1}$) on physiological and psychological variables of endurance performance. EXP performed a 6-day period with daily HIT followed by a 5-day step taper. Testing was performed before the intervention (pre), on the 7th (post-1), and on the 11th day of the intervention (post-2). From pre to post-2, EXP achieved a larger relative improvement than TRAD in VO_{2peak} (4.0 ± 3.7% vs 0.8 ± 1.8%, respectively, P = .041) and the 1-min peak power output from the VO_{2peak} test (5.0 ± 3.6% vs 0.9 ± 1.5%, respectively, P = .009) and had a tendency toward larger improvement in power output at a blood lactate concentration of 4 $mmol•L^{-1}$ (P = .088) and peak isokinetic knee extension (P = .06). The effect size of the relative improvement in the endurance variables revealed a moderate-to-large effect of EXP vs TRAD. In conclusion, this study indicates that elite cyclists performing the present 11-day compressed performance peaking protocol consisting of a 6-day HIT overload followed by a 5-day step taper are superior to a 11-day taper only.

KEYWORDS
endurance, periodization, super-compensation, tapering, training load

1 | INTRODUCTION

Optimization of the training load prior to important competitions is of great importance to ensure peak performance.[1] Functional overreaching is a short-term performance decrement that, when followed by an adequate period of recovery, results in super-compensation and subsequent performance enhancement.[2,3] A usual approach in the search for peak performance is two to four weeks of overload training followed by 1-3 weeks with a reduced load, called a taper.[4] The main purpose of the taper is to reduce stress and residual fatigue of previous training so that sport performance can be optimized.[5] However, with a tight competition schedule, this approach of 3-7 weeks of preparation to prioritized competitions may not be feasible for many elite athletes. Indeed, a study describing the annual training of Olympic and World Champion cross-country skiers and biathletes indicated that these athletes competed repeatedly over several months and

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TABLE 1 Overview of all activity during the intervention period

Day of intervention	EXP	TRAD
1-6	1 daily HIT session	Maintained HIT. Reduced volume of LIT and MIT
7	Post-1 test	Post-1 test
8	Complete rest	60- to 120-min LIT
9	20- to 40-min LIT	20- to 40-min LIT
10	20-min LIT, 2 × 5-min MIT, 3 × 1-min HIT	20-min LIT, 2 × 5-min MIT, 3 × 1-min HIT
11	Post-2 test	Post-2 test

The EXP group performed one daily high-intensity aerobic training (HIT) session during the first 6 d followed by a recovery period during the next 4 d before the post-test, while the TRAD group performed a more traditional taper and reduced their training load by reducing the length of the sessions with low intensity (LIT) and moderate intensity (MIT), and maintain the duration HIT.

therefore did not use overload training followed by tapering strategies before their gold performance.[6] Instead of adding a defined overload period before the taper, a general time-saving alternative across all sports is to simply reduce the training volume by 40%-60% over 11-14 days, and specific to cycling, these recommendations are 21%-60% and 8-14 days, respectively.[7] However, it has been theorized,[8] and experimentally showed,[9] that an overload period before the taper results in higher performance gains than a taper only. Since it has been observed that a functional overreaching can reduce the ergogenic effect of the subsequent taper,[9] an overload period necessitates careful training load management. Furthermore, it has been theorized that an overload phase demands a longer taper period,[8] something that might be difficult in a tight competition schedule.

It has been observed that 7-14 days of overload high-intensity interval training (HIT) leads to improvement in measurements of aerobic fitness following 5-14 days of reduced load.[3,10,11] HIT performed as multiple short intervals have been shown to induce larger performance improvements than continuous 5-minute intervals[12]; therefore, inducing HIT overload by multiple short intervals might be superior to continuous intervals. Additionally, it has been observed that perceived feeling of well-being in the legs was restored within the first week after a 1-week block of 5 HIT sessions in cyclists.[13,14] This indicates that a relatively short block of HIT can be used as an overload period to improve performance prior to major competitions without demanding too much recovery and thus enables a relatively short taper. Furthermore, a single-case study indicates that a 7-day HIT block followed by a 5-day step taper can improve physiological determinants of endurance performance concomitant with an improved well-being in the legs of an elite cyclist.[15] However, to the best of our knowledge, this approach of compressed performance peaking has not been compared with a more normal taper period in elite cyclists.

Therefore, the aim of the present study was to compare the effect of a compressed variant of the recommended overload and tapering approach, consisting of a 6-day HIT overload followed by a 5-day taper, with a 11-day taper that maintained the usual HIT stimulus and reduced the duration of lower exercise intensity, on physiological and psychological variables of endurance performance. We hypothesize that the short overload with a subsequent short taper was superior to the traditional 11-day taper.

2 | MATERIALS AND METHODS

2.1 | Participants

Seventeen male cyclists volunteered for the study. Based on peak oxygen uptake (VO_{2peak}), 1-minute peak power output from the VO_{2peak} test (W_{max}), and training characteristics, the cyclists were classified as elite.[16] The cyclists were assigned and matched to create two homogenous groups based on VO_{2peak} measures during the preceding 6 months: an experimental group performing a 6-day overload followed by a 5-day taper (EXP; n = 9, age 21 ± 7 years, body height: 180 ± 5 cm) and control group performing a traditional 11-day taper (TRAD; n = 8, age 22 ± 8 years, body height 178 ± 8 cm). The cyclists provided written informed consent to participate in the study that was approved by the local ethical committee at Lillehammer University College and performed in accordance with the Declaration of Helsinki.

2.2 | Experimental design

The main objective of the present study was to compare the effect of a short 6-day overload period followed by a 5-day step taper (~55% reduction in training load, Table 1) with a more traditional 11-day taper with ~40% reduction in training load on physiological and performance measurements in elite cyclists. Therefore, no control group that continued their usual training was included. The 6-day overload period in EXP contained one daily HIT session consisting of multiple short intervals.[12] The overload period was followed by a taper period leading to the final test on day 5 after the last HIT session. Peak knee-extension torque at 60° $seconds^{-1}$ ($MVC_{60°}$), cycling economy, power output at 4 $mmol·L^{-1}$ blood lactate concentration ($Power_{4La}$–), VO_{2peak}, W_{max}, and profile of mood states (POMS) were measured in both groups before (pre) the intervention, after 6 days (post-1), and after the 11-day intervention period (post-2). Furthermore, in order to quantify how the EXP and TRAD affected the perceived well-being in the legs during the intervention period, the cyclists reported their perceived feelings on a 9-point

TABLE 2 Percent changes in mean daily endurance training duration in each intensity zone from baseline (mean values from the 4 wk preceding pre-test) to the first 6 d of the intervention and from baseline to the 4 last days before post-2 test

	First 6 d		Last 4 d before post-2	
Intensity zone	EXP	TRAD	EXP	TRAD
LIT (60%-82% of HR_{peak})	−41 ± 21	−28 ± 11	−50 ± 21	−45 ± 13
MIT (83%-87% of HR_{peak})	−8 ± 36	−42 ± 22	−68 ± 9	−69 ± 19
HIT (88%-100% of HR_{peak})	192 ± 81	5 ± 44	−60 ± 0.4	−47 ± 28
Total daily training duration	−18 ± 26	−28 ± 6	−54 ± 17	−48 ± 11
TRIMP	9 ± 32	−26 ± 8	−57 ± 13	−50 ± 13

The EXP group performed one daily high-intensity aerobic training (HIT) session during the first 6 d followed by a recovery period during the next 4 d before the post-test, while the TRAD group performed a more traditional taper and reduced their training load by reducing the length of the sessions with low intensity (LIT) and moderate intensity (MIT), and maintain the duration HIT. Values are mean ± SD.
Abbreviations: HR_{peak}, peak heart rate; TRIMP, Total training load.

scale, going from very very good to very very heavy after each training week.[14]

2.3 | Training intervention

The training intervention started at the end of May. During the four weeks prior to the intervention, the performed training was categorized based on the 3-zone model presented by Sylta et al[17] EXP and TRAD cyclists performed 10.6 ± 2.3 and 11.8 ± 2.3 $h \cdot wk^{-1}$, respectively, of low-intensity training (LIT; 60%-82% of peak heart rate [HR_{peak}]), 1.6 ± 0.7 and 1.6 ± 0.4 $h \cdot wk^{-1}$, respectively, of moderate intensity (MIT; 83%-87% of HR_{peak}), and 1.1 ± 0.2 and 1.1 ± 0.2 $h \cdot wk^{-1}$, respectively, of HIT (88%-100% of HR_{peak}) with no differences between groups ($P > .05$). If training was performed below 60% of peak heart rate, it was registered as LIT. Total training load was calculated as time spent in intensity zones 1, 2, and 3 multiplied by a factor of 1, 2, or 3, respectively.[18] Training during the two days before the pre-testing was standardized for both groups and consisted of low-intensity cycling for 1.5-2.5 hours. An overview of all activity during the intervention period is presented in Table 1. During the 6-day overload period, EXP performed one daily HIT session consisting of 3 sets of 9.5 minute of 30-second work intervals interspersed with 15-second recovery, with 3-minute recovery in between sets.[12] During these HIT sessions, the cyclists were instructed to achieve the highest possible average power output across all three sets. Power output during recovery was 50% of the work intervals. Typically, the work intensity during the 30-second work and 15-second recovery intervals is 85% and 43% of W_{max}, respectively, with a mean intensity during each set of 72% of W_{max}.[12] Therefore, EXP had a large increase in the mean daily HIT volume and a reduction in the LIT and MIT volume in the 6-day overload period compared to the 4 weeks prior to the intervention ending up in a similar total training load ($P > .05$) in these two periods (Table 2 and Figure 1). The TRAD group maintained their HIT training frequency and reduced their

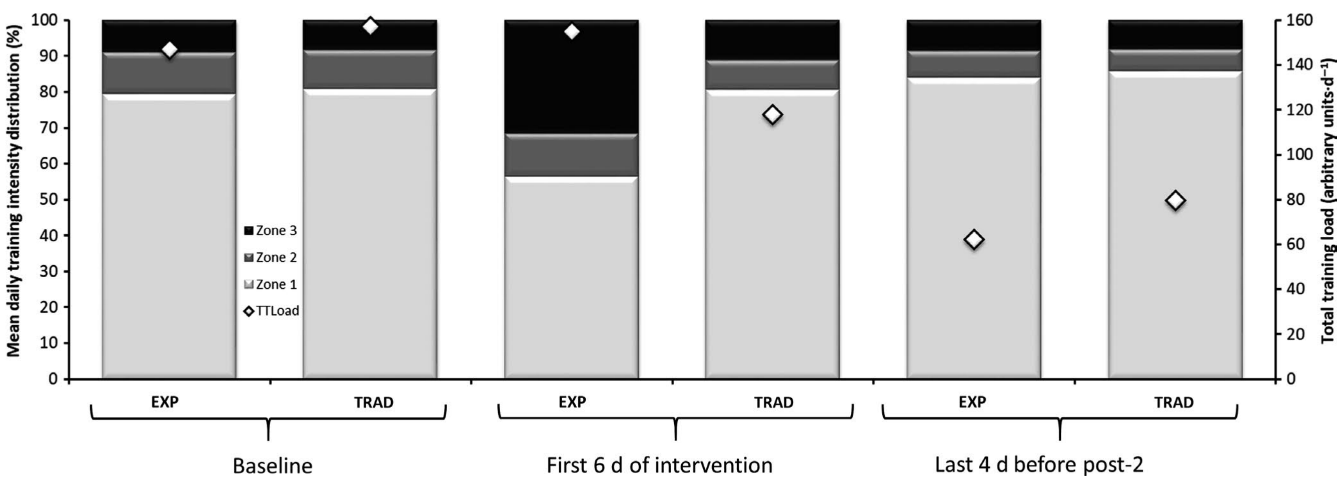

FIGURE 1 Mean daily training load during the 4 wk prior to pre-test (baseline), during the first 6 d of the intervention period, and during the 4 d before post-2 test. The EXP group performed one daily high-intensity aerobic training (HIT) session during the first 6 d followed by a recovery period during the next 4 d before the post-test, while the TRAD group performed a more traditional taper and reduced their training load by reducing the length of the sessions with low intensity (LIT) and moderate intensity (MIT), and maintain the duration HIT. The figure shows percentage distribution of the different intensity zones (columns) and total training load (TTLoad; white diamond)

LIT and MIT training during the first 6 days of the 11-day intervention period, leading to a 26 ± 8% reduction in total training load compared to the 4 weeks prior to the intervention (Table 2 and Figure 1). During these first 6 days of the intervention period, EXP had a significantly larger total training load and HIT volume, but a lower LIT volume than TRAD ($P < .05$).

For EXP, there was a large reduction in MIT and HIT ($P < .05$) during the 5-day taper (Table 2 and Figure 1). The 1st day consisted of incremental tests to determine $Power_{4La}-$ and VO_{2peak}, while the 2nd day was complete rest. On the 3rd day, the cyclists performed 20- to 40-minute easy cycling, and the 4th day contained 20 minute of warm-up followed by 2 × 5 min of moderate intensity and thereafter 3 × 1 min with gradually increasing intensity toward W_{max}. The final test session was on day 5. In this 5-day period, TRAD had a further reduction across all intensity zones, ending up with a daily reduction of 50 ± 13% in training load compared to the four weeks prior to the intervention (Table 2 and Figure 1). The 1st day consisted of incremental tests to determine $Power_{4La}-$ and VO_{2peak} followed by a 2 × 4-minute, 2 × 3-minute, 2 × 2-minute, and 2 × 1-minute HIT session. On the 2nd and 3rd days, the cyclists performed LIT training with 50% of normal duration (~1 to 2 hours), while the 4th and last day before the final test, session was identical to EXP. There were no differences in training load and time in different intensity zones during the 5-day taper period between EXP and TRAD ($P > .05$). The overall decrease in total training load during the 11-day intervention period was larger for TRAD than EXP (35 ± 8% vs 17 ± 21%, respectively, $P < .05$).

2.4 | Testing

Each test was standardized for meal, temperature, testing time of day, cycle adjustments, and warm-up. All cycling tests were performed on a Lode Excalibur Sport ergometer (Lode BV, Groningen, the Netherlands). Before the exercise test session, the cyclists filled out the POMS questionnaire to assess the six specific mood states vigor, depression, confusion, fatigue, anger, anxiety, and confusion.[19] T-scores were calculated based on normative values in athletes reported in Terry and Lane[20] so that a T-score of 50 represents the average score reported for the similar club-level athletes. Thereafter, the test session started with a 10-min warm-up before $MVC_{60°}$ in the dominant leg was assessed in a Cybex 6000 dynamometer (Lumex, Ronkonkoma, NY, USA). Four warm-up attempts were followed by three maximal effort attempts separated by 60 seconds. The best $MVC_{60°}$ attempt was used for analyses. Thereafter, $Power_{4La}-$ was determined by plotting [La^-] vs power output during submaximal continuous incremental cycling.[21] The cycling test started with 5 minutes at 125 W, followed by 50 W increments every 5 minutes. Blood was sampled from a fingertip at the end of each 5-minute bout and analyzed for whole blood [La^-] using a portable lactate analyzer (Lactate Pro LT-1710, Arcray Inc Kyoto, Japan). The test was terminated at a [La^-] of 4 mmol•L^{-1} or higher. At the power output of 225 W during this incremental test, gross efficiency (GE) was calculated with the average VO_2 and RER values between 3 and 5 minutes and updated table of non-protein respiratory quotient.[22] VO_2 was measured using a computerized metabolic system with mixing chamber (Oxycon Pro, Erich Jaeger, Hoechberg, Germany) with standard calibration procedures. After 5-minute recovery, an incremental test for determination of VO_{2peak} was completed. This test was initiated with 1 minute of cycling at a power output corresponding to 3 W·kg^{-1} (rounded down to the nearest 50 W). Power output increased by 25 W every minute until exhaustion, defined when the cyclists cadence fell below 60 rpm despite strong verbal encouragement. VO_{2peak} was calculated as the average of the two highest 30-second VO_2 measurements. W_{max} was calculated as the mean power output during the last minute of the incremental test, and HR_{peak} was the highest HR during the VO_{2peak} test.

2.5 | Statistical analyses

A mixed-design ANOVA with group (TRAD vs EXP) as between-subject factor, and time point during the study as within-subject factor, was applied to investigate changes over time within groups and possible interaction between time and group. Where the sphericity assumption was violated, the Greenhouse-Geisser procedure was used to correct the degrees of freedom. A significant interaction between time and group was followed up with pairwise comparisons with Bonferroni adjustment to compare each group's mean across different time points and within-subject changes in each group between different time points. All reported p-values form these test are Bonferroni-adjusted. Comparisons between the groups at pre, in percent change from pre to post-2 in training load and training volume, were investigated using independent-sample *t* tests. Effect sizes (ES) were calculated as Cohen's d between the groups' percent change from pre to post-2 to elucidate on the practical significance of the different taper protocols. The criteria to interpret the magnitude were the following: 0-0.2 = trivial, 0.2-0.6 = small, 0.6-1.2 = moderate, 1.2-2.0 = large, and ˃2 = very large.[23] All analyses resulting in $P \leq .05$ were considered statistically significant. *P*-values below 0.10 were considered as tendencies. Values are mean ± standard deviation unless otherwise stated. All statistical analysis was done in IBM SPSS (IBM SPSS Statistics, version 24, IBM Corp.) and Microsoft Excel 2010 (Microsoft Corporation).

TABLE 3 Mean and standard deviation from the physiological tests before (pre), after 6 d (post-1), and on the 11th day of the intervention period (post-2)

	EXP			TRAD		
	Pre	Post-1	Post-2	Pre	Post-1	Post-2
Body mass (kg)	70.6 ± 8.4	70.2 ± 7.8	70.1 ± 7.6	70.5 ± 8.6	70.6 ± 8.5	70.3 ± 8.7
VO_{2max} test						
VO_{2peak} ($mL\cdot min^{-1}$)	5396 ± 617	5485 ± 583	5570 ± 513*,†	5192 ± 776	5191 ± 856	5218 ± 809
($mL\cdot min^{-1}\cdot kg^{-1}$)	76.8 ± 6.9	78.3 ± 5.3	79.7 ± 4.9*,#	73.5 ± 4.1	73.3 ± 5.6	74.1 ± 4.4
RER_{peak}	1.13 ± 0.05	1.12 ± 0.04	1.14 ± 0.03	1.13 ± 0.03	1.14 ± 0.04	1.13 ± 0.03
HR_{peak} ($beats\cdot min^{-1}$)	189 ± 10	186 ± 10	192 ± 8	191 ± 12	193 ± 11	193 ± 10
$[La^-]_{end}$ ($mmol\cdot L^{-1}$)	11.5 ± 2.2	12.0 ± 3.0	13.1 ± 2.1	12.2 ± 1.9	11.7 ± 1.7	12.0 ± 1.7
RPE	19.0 ± 0.7	19.2 ± 0.8	19.4 ± 0.7	19.6 ± 0.5	19.7 ± 0.5	19.6 ± 0.5
W_{max} ($W\cdot kg^{-1}$)	6.43 ± 0.46	6.48 ± 0.54	6.75 ± 0.46*,#	6.21 ± 0.33	6.25 ± 0.33	6.26 ± 0.29
Submaximal test						
$Power_{4mmol\cdot L^{-1}}$ ($W\cdot kg^{-1}$)	4.47 ± 0.35	4.59 ± 0.33*	4.62 ± 0.38*,†	4.25 ± 0.33	4.23 ± 0.35	4.27 ± 0.39
GE@225 W (%)	19.6 ± 1.5	19.4 ± 1.1	20.0 ± 1.8	19.1 ± 0.5	19.4 ± 0.5	18.9 ± 0.6
Peak torque						
Isokinetic knee-extension$_{60°\cdot sec^{-1}}$ (Nm)	184 ± 36	180 ± 34	196 ± 37**	179 ± 28	174 ± 48	173 ± 46

The EXP group performed one daily high-intensity aerobic training (HIT) session during the first 6 d followed by a recovery period during the next 4 d before the post-test, while the TRAD group performed a more traditional taper and reduced their training load by reducing the length of the sessions with low intensity (LIT) and moderate intensity (MIT), and maintain the duration of HIT.

Abbreviations: $[La^-]_{end}$, blood lactate concentration one min after exercise; GE, gross efficiency; HR_{peak}, peak heart rate; $Power_{4\,mmol\cdot L^{-1}}$, power output at a blood lactate concentration of 4 mmol•L^{-1}; RER_{peak}, peak respiratory exchange ratio; RPE, rate of perceived exertion; VO_{2peak}, peak oxygen consumption; W_{max}, peak aerobic power output.

*Different from pre ($P < .05$).

**Different from post-1 ($P < .05$).

#The relative change from pre is larger than in TRAD ($P < .05$).

†The relative change from pre tends to be different from TRAD ($P < .1$ and $>.05$).

3 | RESULTS

3.1 | Baseline

There were no significant differences in any of the physiological or performance measurements between EXP and TRAD before the intervention period (Table 3).

3.2 | Body mass, VO_{2peak}, and W_{max}

Body mass did not significantly change during the intervention in any of the two groups (Table 3). For VO_{2peak}, there was a significant effect of time ($F(2,30) = 4.77$, $P = .016$) but no significant time*group interaction ($F(2,30) = 2.18$, $P = .131$). From pre to post-2, EXP increased VO_{2peak} by 4.0 ± 3.7% ($P = .003$), while there was no significant change in TRAD (0.8 ± 1.8%, $P = 1.0$; Figure 2). There was a larger percentage increase from pre to post-2 in EXP than TRAD ($P = .041$) with a moderate ES (ES = 1.1). For W_{max}, there was a significant effect of time ($F(2.30) = 9.90$, $P < .001$) and a significant time*group interaction ($F(2,30) = 6.36$, $P = .005$). W_{max} increased ($P < .001$) by 5.0 ± 3.6% from pre to post-2 in EXP, but did not change significantly in TRAD (0.9 ± 1.5%, $P = 1.0$; Figure 2), and the percentage improvement during this period was larger ($P = .009$) in EXP than TRAD with a large ES favoring EXP (ES = 1.5). For $[La^-]_{end}$, there was no significant effect of time ($F(2,30) = 2.29$, $P = .119$) but a tendency to a significant time*group interaction ($F(2,30) = 2.76$, $P = .079$). $[La^-]_{end}$ increased from pre to post-2 in EXP by 14.7 ± 13.6% ($P = .014$), while there was no significant change in TRAD (−1.3 ± 9.7%, $P = 1.0$; Table 3). There was a larger percentage increase from pre to post-2 in EXP than TRAD ($P = .014$) with a large ES (ES = 1.4). There was a significant effect of time ($F(2,30) = 3.52$, $P = .042$) and a significant time*group interaction ($F(2,30) = 4.19$, $P = .025$) for HR_{peak}. This was because of an increase in HR_{peak} in EXP from post-1 to post-2 ($P < .001$). No other changes occurred in HR_{peak} in neither group during the study, and the ES in percent change from pre to post-2 between groups was small (ES = 0.30). There was no significant effect of time ($F(2,30) = 0.99$, $P = .384$) or a significant time*group interaction ($F(2,30) = 0.99$, $P = .384$) for RPE recorded after the VO_{2peak} protocol (Table 3) and only a moderate ES in percent change between groups (ES = 0.60).

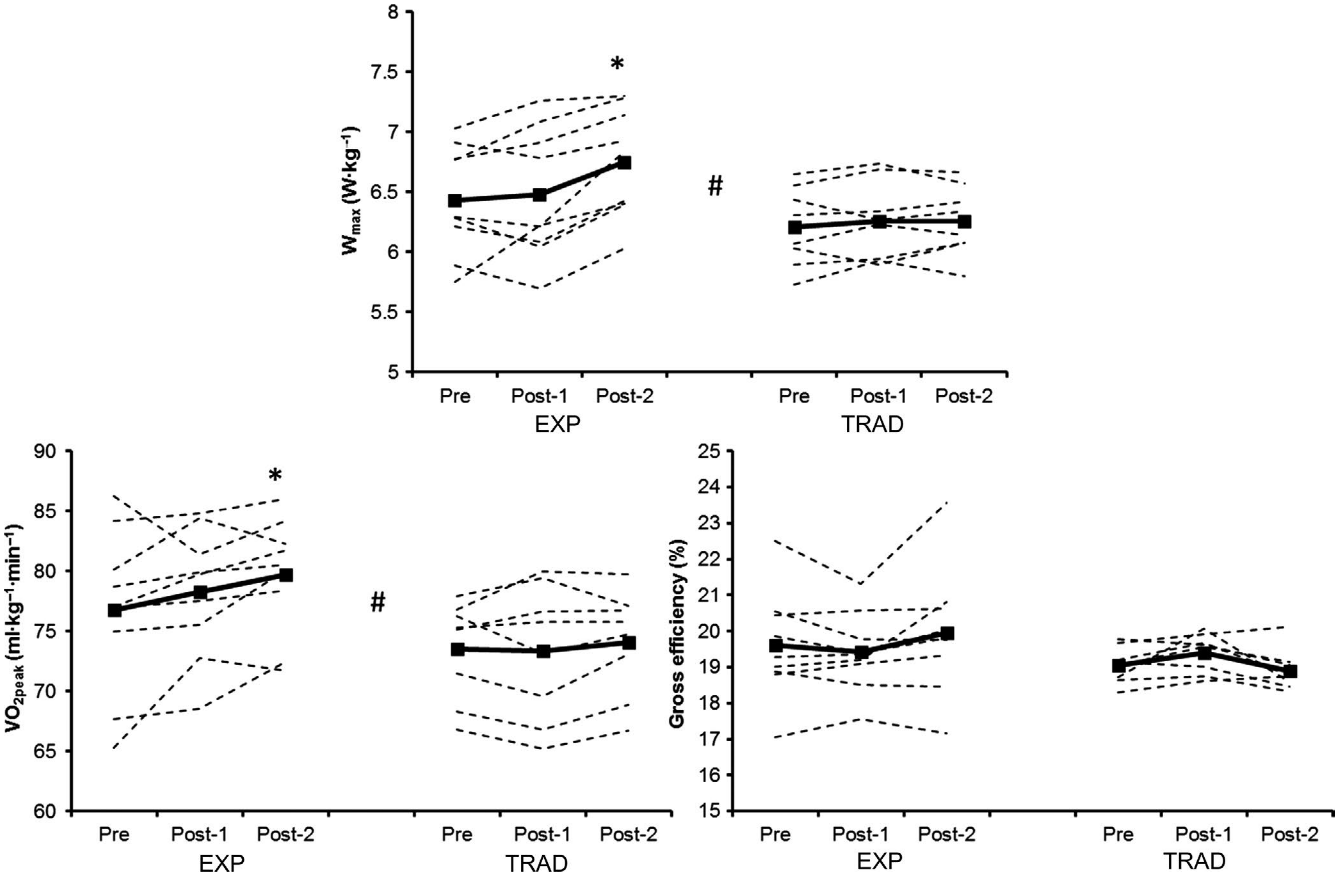

FIGURE 2 Individual data points and mean values (solid line) for peak aerobic power output (W_{max}; upper panel), peak oxygen uptake (VO_{2peak}; lower left panel), and gross efficiency at 225 W (lower right panel) before (Pre), after 6 d of the intervention (post-1), and on the 11th day (last day) of the intervention (post-2) for the experimental group (EXP) and the traditional group (TRAD). *Larger than at Pre ($P < .05$), #The relative change from pre to post-2 is larger in EXP than in TRAD ($P < .05$)

3.3 | *Gross efficiency, power output at 4 mmol·L^{-1}, and MVC$_{60°}$*

There was no significant effect of time ($F(2,30) = 0.23$, $P = .799$) but a significant time*group interaction in GE ($F(2,30) = 5.58$, $P = .009$). Despite this, no significant changes in GE could be detected within groups (Table 3, Figure 2). There was no significant difference between EXP and TRAD in the percent point change in GE from pre to post-2 ($P = .125$). However, there was a moderate ES in this change in GE from pre to post-2 in favor of EXP (ES = 0.81; Figure 2). There was a significant effect of time ($F(2,30) = 4.47$, $P = .044$) and a tendency to a time*group interaction ($F(2,30) = 3.08$, $P = .061$) in power output at 4 mmol•L^{-1} [La^{-}]. EXP increased power output at 4 mmol•L^{-1} [La^{-}] from pre to post-1 by 2.7 ± 2.5% ($P = .033$) and from pre to post-2 by 3.1 ± 2.8% ($P = .023$), while no significant changes occurred in TRAD (0.4 ± 3.4%, $P = .74$; Figure 3). There was a tendency toward larger improvement from pre to post-2 in EXP than TRAD ($P = .088$), with the ES showing a moderate effect of EXP vs TRAD (ES = 0.88). There was no significant effect of time ($F(2,30) = 2.17$, $P = .138$) or a significant time*group interaction ($F(2,30) = 1.49$, $P = .247$) in MVC$_{60°}$. However, despite no significant changes occurred from pre to post-1 or pre to post-2, there was a numerical increase of 9.1 ± 5.4% ($P = .13$) from post-1 to post-2 in EXP. No significant changes in MVC$_{60°}$ occurred in TRAD (Table 3). There was a tendency to larger percentage improvement from pre to post-2 in EXP than TRAD ($P = .060$) with a small ES favoring EXP (ES = 0.47).

3.4 | POMS and perceived well-being in the legs

There was a significant effect of time ($F(2,26) = 5.80$, $P = .008$) and a tendency to a time*group interaction ($F(2,26) = 2.91$, $P = .072$) in fatigue. EXP had a tendency to increased fatigue from 49.0 ± 8.1 at pre to 53.8 ± 10.4 at post-1 ($P = .052$) before it significantly decreased from post-1 to 45.6 ± 6.7 at post-2 ($P = .007$; Table 4). No other significant changes occurred in the different POMS items in neither EXP nor TRAD. During the intervention period, there was no significant change in perceived well-being in the legs within groups. However, at day 11 (last day of the taper) EXP had a better perceived well-being in the legs than TRAD (3.0 ± 1.3 vs 5.1 ± 0.8, respectively, $P = .002$) and the improvement in well-being of the legs from pre to post-2 was larger in EXP than TRAD ($P = .040$; Figure 4).

4 | DISCUSSION

The primary findings in the present study support our stated hypothesis that a compressed variant of the overload, via multiple short HIT intervals, and tapering approach induces superior increases in physiological determinants of endurance performance compared to a traditional taper approach in elite cyclists. Cyclists performing EXP experienced a larger improvement in VO_{2peak} and W_{max} from pre to post-2. Furthermore, there were tendencies toward superior improvement in power output at 4 mmol•L^{-1} [La^-] and cycling economy in EXP vs TRAD. The ES of the relative improvement in these variables revealed a moderate-to-large effect of EXP vs TRAD.

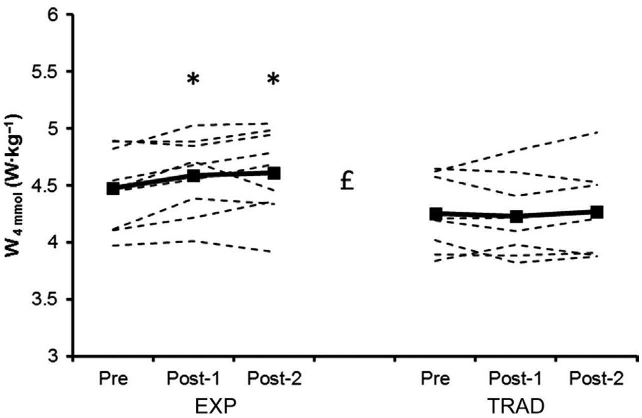

FIGURE 3 Individual data points and mean values (solid line) for power output at 4 mmol·L^{-1} blood lactate (W_{4mmol}) before (Pre), after 6 d of the intervention (post-1), and on the 11th day (last day) of the intervention (post-2) for the experimental group (EXP) and the traditional group (TRAD). *Larger than at Pre ($P < .05$), £The relative change from pre to post-2 tends to be larger in EXP than in TRAD ($P < .1$ and $>.05$)

The compressed performance peaking, consisting of 6-day HIT overload followed by 5-day taper, improved our primary indicator of performance, W_{max}, by 5% with a large effect of EXP compared to TRAD. W_{max} is considered particularly important for endurance performance in elite cyclists[24] and is influenced by factors such as VO_{2max}, exercise economy, anaerobic capacity, and neuromuscular characteristics.[25] Accordingly, the ES also showed a moderate effect of EXP vs TRAD on VO_{2peak}, cycling economy, and small effect on $MVC_{60°}$. The present improvement in W_{max} is similar to the 5.4% improvements in W_{max} of well-trained triathletes after a 3-week overload period followed by a 2-week tapering[9] and in the upper range of the 0.5%-6.0% expected taper-induced performance improvements.[5] Therefore, the performance-enhancing effects of a 5-week overload and taper approach can be achieved by the present 11-day compressed HIT overload and tapering strategy. In the study of Aubry et al,[9] it was observed that the athletes who had a functional overreaching (defined as a mean decrement of 2% in W_{max}) after the 3-week overload period had a poor performance super-compensation during the subsequent taper. Coutts et al[26] compared performance changes in well-trained triathletes after either 4 weeks of overload training followed by a 2-week taper or 4 weeks of normal training and a similar taper. They observed ~4% reduction of performance during the overload phase, and consequently, there were no differences between groups in performance gain after the taper. Even though

TABLE 4 Mean and standard deviation of the T-scores from the profile of mood states questionnaire before (pre), after 6 d (post-1) and on the 11th day of the intervention period (post-2)

	EXP			TRAD		
	Pre	**Post-1**	**Post-2**	**Pre**	**Post-1**	**Post-2**
Tension	45.1 ± 6.4	46.5 ± 7.8	43.6 ± 5.7	48.4 ± 4.2	46.5 ± 7.8	43.6 ± 5.7
Depression	47.7 ± 6.8	47.5 ± 6.9	44.2 ± 5.0	49.3 ± 8.2	47.6 ± 9.3	48.6 ± 8.9
Anger	48.7 ± 6.8	49.8 ± 5.7	47.8 ± 5.8	49.0 ± 5.0	49.6 ± 9.6	50.7 ± 8.3
Fatigue	49.0 ± 8.1	53.8 ± 10.4†	45.6 ± 6.7	50.4 ± 6.9	48.3 ± 9.2	46.2 ± 9.6
Confusion	49.5 ± 6.5	48.4 ± 6.3	45.5 ± 5.6	53.0 ± 8.8	47.0 ± 8.0	46.2 ± 10.2
Vigor	50.9 ± 6.9	48.9 ± 7.9	53.1 ± 5.2	57.1 ± 6.9	47.8 ± 10.9	53.0 ± 8.5
Vigor - fatigue	8.6 ± 4.4	4.6 ± 7.6	11.9 ± 4.8	11.4 ± 6.3	8.3 ± 6.2	11.5 ± 8.2

The EXP group performed one daily high-intensity aerobic training (HIT) session during the first 6 d followed by a recovery period during the next 5 d before the post-test, while the TRAD group performed a more traditional taper and reduced their training load by reducing the length of the sessions with low and moderate intensity, and maintain the duration of HIT. Vigor - fatigue is calculated by subtracting the fatigue t-score from the vigor t-score.

Abbreviation: TMD, total mood disturbance.

*Different from pre ($P < .05$).

†Tendency to different from previous time point ($P < .1$ and $>.05$).

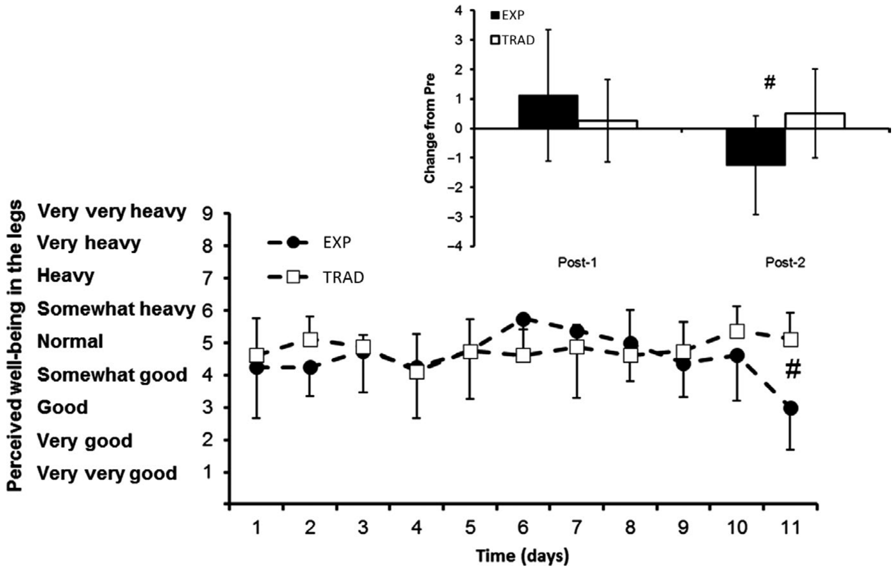

FIGURE 4 Perceived well-being in the legs during the 11-d intervention period for the experimental group (EXP) and the traditional group (TRAD). Changes from pre-test to the 6th (post-1) and 11th (post-2) day of the intervention are shown in the small upper panel. #Difference between groups ($P < .05$)

contradictory studies exist,[27] this may be interpreted as a pronounced performance reduction during the overload period might counteract the taper effect, and thus jeopardize the potential performance-enhancing effects of the overload and taper approach. The risk for a pronounced reduction in performance after the overload period might be reduced by a shorter overload phase, like the present 6-day HIT overload, which, at group level, did not induce any reduction in the measured physiological variables. However, we did notice that some cyclists had a reduction in W_{max} after the HIT overload, but there seem to be no uniform negative consequences of this, as after the taper one of them improved W_{max} by 8.7% and the other improved by 0.3% from pre.

Larger improvement in VO_{2peak} is likely the main reason to a tendency toward a larger increase in power output at 4 mmol•L^{-1} [La$^-$] in EXP vs TRAD. Although no significant changes in neither groups, changes in GE could also have contributed to the tendency toward larger increase in power at 4 mmol•L^{-1} [La$^-$] since there was a moderate ES in favor of EXP from pre to post-2. On the one hand, there is literature that indicates that cycling economy is quite stable and that there is no difference between elite cyclists and recreational level cyclists,[28] while on the other hand, there is literature indicating that HIT training can improve it.[29] Actually, after a 7-day HIT block with multiple short intervals, it was observed improved cycling economy in competitive cyclists.[10] The finding of a ~6% increase in $MVC_{60°}$ in EXP at post-2 in the present study is in agreement with a single-case study on an elite MTB junior cyclist, who after a 13-day compressed overload and tapering protocol achieved a 4%-7% increase in muscle contractile function.[15] After a 4-week overload period, others have also reported improved contractile function after a week of tapering.[30]

Despite no performance reduction at the group level, EXP experienced a tendency toward increased perceived fatigue on the POMS fatigue item after the 6-day HIT overload, but this was completely recovered on the 5th day of the taper. Other research groups have also observed this pattern of increased fatigue, measured by POMS, after an overload period with a rather quick recovery after one week of taper.[9] Although not significantly, the rate of perceived well-being in the legs seemed to followed the same pattern, with heavier legs on the last day of the HIT overload period and actually significantly better legs on the 5th day of the taper compared to TRAD. No changes occurred in these subjective variables in TRAD, and this is similar to another group of cyclists performing a normal taper without any prior overload phase.[9] A rather quick recovery of perceived well-being of the legs has also been observed in cyclists after a week with HIT overload.[13,14] Maybe the short duration of the present HIT overload did not induce enough fatigue to induce performance reductions at the group level, resulting in a fast recovery of the psychological factors and a super-compensation of the physiological variables. Despite the present HIT overload increased the daily amount of HIT training by 192%, the concomitant reduction in LIT and MIT resulted in no change in total training load from the baseline period. Therefore, it could be argued that it was no training overload during the 6-day HIT overload period in EXP. However, the tendency toward a larger fatigue and feeling of heavier legs toward the end of this period indicate the opposite. In agreement with the present finding in EXP, previous studies have observed that a one-week HIT block with 5-7 HIT sessions improves cyclists' endurance performance[10] and physiological determinants of endurance performance.[14] In line with the latter, it has been suggested that block training seems well suited to improve performance in elite athletes with years of training[4,31] and that well-trained endurance athletes need HIT for further performance improvements.[32]

It might be somewhat surprising that EXP already on the 5th day of taper improved the physiological variables. However, even after 2-4 weeks of overload there have been observed improvement after only one week of taper in such variables.[9,27,30] Therefore, it seems reasonable that a 5-day taper may be enough time to achieve a super-compensation and a step taper was chosen to increase probability of recovery and super-compensation already on the 5th day after the overload period.[33] It was somewhat unexpected that the TRAD group, with 11 days of tapering, did not improve any of the measured variables. Since TRAD had a 50% reduction in total training load during the last 5 days of the intervention, while EXP had a 57% reduction, it could be suggested that lack of recovery in TRAD is a reason to no improvement in TRAD. However, during the entire 11-day intervention period TRAD reduced their total training load by 35% (which is within the recommendations of a traditional taper for cyclists),[7] while EXP reduced the total training load by 17%, indicating that there should not be less recovery in TRAD than EXP. Furthermore, none-to-small ergogenic effects of a traditional tapering period without prior overload have also been observed in trained and well-trained triathletes.[9,26] It is also important to remember the high training status of the present elite cyclists, together with the fact that they were already well into their competition season when the intervention started, gives them a small window for further performance enhancement. Some limitations of the present study may be related to the experimental design, specifically the small sample size and lack of direct performance measurement, and it would be interesting to measure more specific muscle contractions abilities like a Wingate test instead of isokinetic strength. It could be argued that the differences between the groups in reduced total training load are a limitation, but since we are comparing two different performance peaking strategies with intrinsic difference in training load, this is difficult to avoid. The multiple short intervals used in the present overload period in EXP have previously been shown to be superior to more traditional 5-minute HIT intervals, so whether it is the specific HIT sessions or the compressed overload and taper protocol per se that induced the positive effect remains unknown.[12]

In conclusion, elite cyclists performing the present 11-day compressed performance peaking protocol consisting of a 6-day HIT overload followed by a 5-day step taper induced a larger improvement in VO_{2peak} and W_{max} and tendencies toward a larger improvement in power output at 4 mmol•L^{-1} [La^{-}] and cycling economy compared to a 11-day taper only. The advantage of the compressed protocol was underlined by the ES of the relative improvement of these variables, which revealed a large-to-moderate effect of performing EXP vs TRAD.

4.1 | Perspectives

The results in this study indicate that the present compressed HIT overload and taper protocol can improve variables related to endurance performance in elite cyclists. This compressed peaking protocol consisted of a 6-day overload period with daily short-interval HIT sessions followed by a 5-day step taper and can be a starting point when athletes have a short period (eg, 2 weeks) to peak their performance before an important competition. Importantly, it is difficult to generalize the results from the present study and we recommend athletes to look closer into their optimal overload and tapering plans. General recommendations for performance peaking should be individually adapted, to account for individual differences in training status and differences in capacity to recover from training stress. The present findings might be applicable to similar aerobic sports, but caution is advised if trying to apply such an intense HIT overload to sports like running, since the increased impact may increase the injury risk and recovery demands. More studies in other endurance sports are necessary to establish if this compressed overload and taper procedure can be generalized to be beneficial for peaking of endurance performance.

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CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

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