**Title**

Meta-analyses of the effects of high-intensity interval training in elite athletes – Part I: mean effects on various performance measures

**Supplementary appendix**

**This appendix formed part of the original submission**

**Running title**

Effects of HIIT on various performance measures

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Search string

The search string used in the electronic bibliographic databases PubMed, Scopus, SPORTDiscus, and Web of Science, was conducted in the title, abstract and keywords, combined a population of highly endurance-trained individuals with different aerobic, anaerobic or neuromuscular performance-related outcomes” athlete\*” OR “elite” OR “welltrained” OR “well trained” OR “international level” OR “trained” OR “first league” OR “premier league” OR “division 1” OR “national team” AND “high intensity interval training” OR “high intensity intermittent training” OR “high intensity training” OR “HIIT” OR “HIIT” OR “sprint interval training” OR “repeated sprint training” OR “SIT” OR “repeated sprint exercise\*” OR “RSE” OR “RST” OR “RSA” OR “multiple sprint” OR “repeated-sprint sequence\*” OR “high intensity endurance training” OR “speed endurance training” OR “speed endurance production” OR “speed endurance maintenance” OR “aerob\* exercise” OR “aerob\* high intensity” OR “Tabata” OR “all-out” OR “wingate” OR “anaerob\* exercise” OR “anaerob\* high intensity” and filtered for „humans“, „journal article“, „peer reviewed“, „English“ and „German“ if possible, with the search settings of the databases on the World Wide Web.

|  |  |  |
| --- | --- | --- |
| Table 1. Quality assessment criteria, adapted from Galna et al. [1] | | |
| **Criterion** | **Question** | **Categories** |
| 1 | Research aims or questions stated clearly | 1-yes; 0.5 yes; lacking  detail or clarity; 0 -no |
| 2 | Participants detailed | number, age, sex, height, body mass |
| 3 | Recruitment and sampling methods described | 1-yes; 0.5 yes; lacking  detail or clarity; 0 -no |
| 4 | Inclusion and exclusion criteria detailed | 1-yes; 0.5 yes; lacking  detail or clarity; 0 -no |
| 5 | Controlled co-variates | age, sex, baseline values |
| 6 | Key outcome variables clearly described | 1-yes; 0.5 - only some defined; 0.5-yes, lacking detail or clarity; 0-no |
| 7 | Adequate methodology able to repeat study | participants sampling, equipment, procedure, data processing, statistical analysis |
| 8 | Methodology able to answer research question | participants sampling, equipment, procedure, data processing, statistical analysis |
| 9 | Reliability of the methodology stated | 1-yes, 0.5 yes, lacking  detail or clarity; 0 -no |
| 10 | Internal validity of the methodology stated | 1- yes, 0 - no |
| 11 | Research questions answered adequately in the discussion | 1- yes, 0 - no |
| 12 | Key findings supported by the results | 1- yes, 0 - no |
| 13 | Key finding interpreted in a logical manner which is supported by references | 1- yes, 0 - no |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 2. Quality assessment scores | | | | | | | | | | | | | | | |
| **Source for endurance athletes** | **Criterion** | | | | | | | | | | | | | | **Total** |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **(0-13)** | |
| Clark et al. [2] | 0.5 | 0.7 | 0.5 | 0 | 0 | 0.5 | 0.9 | 0.9 | 0 | 1 | 1 | 1 | 1 | 8.0 | |
| Hanstock et al. [3] | 1 | 0.5 | 0.5 | 0 | 0.5 | 0.5 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 8.8 | |
| Johansen et al. [4] | 1 | 1 | 0.5 | 0.5 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 9.0 | |
| Laursen et al. [5] | 1 | 1 | 0.5 | 0.5 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 10.5 | |
| Menz et al. [6] | 1 | 1 | 0.5 | 0.5 | 0.5 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 10.5 | |
| Rønnestad et al. [7] | 1 | 0.7 | 0.5 | 0.5 | 0 | 1 | 0.9 | 0.9 | 0.5 | 1 | 1 | 1 | 1 | 10.0 | |
| Salazar-Martínez et al. [8] | 1 | 1 | 0.5 | 0.5 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 10.0 | |
| Sandbakk et al. [9] | 1 | 1 | 0.5 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 10.5 | |
| Sandbakk et al. [10] | 1 | 0.7 | 0.5 | 0 | 0.5 | 1 | 0.9 | 0.9 | 0.5 | 1 | 1 | 1 | 1 | 10.0 | |
| Skovereng et al. [11] | 1 | 0.7 | 0.5 | 0 | 0.5 | 1 | 0.9 | 0.9 | 0.5 | 1 | 1 | 1 | 1 | 10.0 | |
| Smith et al. [12] | 1 | 0.5 | 0.5 | 0 | 0 | 1 | 0.8 | 0.9 | 0 | 1 | 1 | 1 | 1 | 8.7 | |
| Stenqvist et al. [13] | 0.5 | 1 | 0.5 | 1 | 0 | 1 | 1 | 0.9 | 0.5 | 0.5 | 1 | 1 | 1 | 10.4 | |
| Stepto et al. [14] | 0.5 | 1 | 0.5 | 0 | 0 | 1 | 0.9 | 0.9 | 0 | 1 | 1 | 1 | 1 | 8.8 | |
| Stevens et al. [15] | 1 | 0.8 | 0.5 | 0 | 0 | 1 | 0.8 | 0.9 | 0.5 | 1 | 1 | 1 | 1 | 9.5 | |
| Stöggl et al. [16] | 1 | 0.6 | 0.5 | 0.5 | 0 | 1 | 1 | 0.9 | 0.5 | 1 | 1 | 1 | 1 | 10.0 | |
| Sylta et al. [17] | 1 | 0.6 | 1 | 1 | 0.5 | 1 | 0.9 | 0.9 | 0 | 1 | 1 | 1 | 1 | 10.9 | |
| **Source for non-endurance athletes** | **Criterion** | | | | | | | | | | | | | **Total** | |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **(0-13)** | |
| Akdoğan et al. [18] | 1 | 0.8 | 0.5 | 0.5 | 0 | 1 | 1 | 0.9 | 0 | 1 | 1 | 1 | 1 | 9.7 | |
| Breil et al. [19] | 1 | 1 | 0.5 | 0.5 | 0.5 | 1 | 0.9 | 0.9 | 0.5 | 1 | 1 | 1 | 1 | 10.8 | |
| Chtara et al. [20] | 1 | 0.7 | 0.5 | 0 | 0 | 1 | 0.9 | 0.9 | 1 | 1 | 1 | 1 | 1 | 10.0 | |
| Dupont et al. [21] | 1 | 0.7 | 0.5 | 0 | 0 | 1 | 0.8 | 0.7 | 0 | 0 | 1 | 1 | 1 | 6.7 | |
| Helgerud et al. [22] | 1 | 0.7 | 0.5 | 0.5 | 0 | 1 | 0.8 | 1 | 1 | 1 | 1 | 1 | 1 | 10.5 | |
| Hermassi et al. [23] | 0.5 | 1 | 0.5 | 0.5 | 0 | 1 | 1 | 0.9 | 1 | 1 | 1 | 1 | 1 | 10.4 | |
| Iaia et al. [24] | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0.9 | 0 | 1 | 1 | 1 | 1 | 10.9 | |
| Liu et al. [25] | 1 | 1 | 0.5 | 0.5 | 0 | 1 | 1 | 0.9 | 0 | 1 | 1 | 1 | 1 | 9.9 | |
| Purkhús et al. [26] | 1 | 1 | 0.5 | 0.5 | 0 | 1 | 0.6 | 0.9 | 0.5 | 0 | 1 | 1 | 1 | 9.0 | |
| Selmi et al. [27] | 1 | 0.5 | 0.5 | 0.5 | 0 | 1 | 0.8 | 0.8 | 0 | 1 | 1 | 1 | 1 | 9.1 | |
| Sheykhlouvand et al. [28] | 1 | 0.7 | 0.5 | 0.5 | 0 | 1 | 0.9 | 1 | 0.5 | 1 | 1 | 1 | 1 | 10.1 | |
| Sheykhlouvand et al. [29] | 1 | 0.7 | 0.5 | 0.5 | 0 | 1 | 0.9 | 1 | 0 | 1 | 1 | 1 | 1 | 9.6 | |
| Sheykhlouvand et al. [30] | 1 | 0.7 | 0.5 | 0.5 | 1 | 1 | 0.9 | 1 | 0 | 1 | 1 | 1 | 1 | 10.6 | |
| Soares-Caldeira et al. [31] | 1 | 0.8 | 0.5 | 1 | 0 | 1 | 0.8 | 0.9 | 0.5 | 1 | 1 | 1 | 1 | 10.5 | |
| Thomassen et al. [32] | 0.5 | 0.7 | 0.5 | 0 | 0 | 1 | 1 | 0.9 | 0.5 | 1 | 1 | 1 | 1 | 9.1 | |
| Venturelli et al. [33] | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0.9 | 0 | 1 | 1 | 1 | 1 | 10.9 | |
| Wells et al. [34] | 0.5 | 0.7 | 0.5 | 0.5 | 0 | 1 | 1 | 0.9 | 0 | 1 | 1 | 1 | 1 | 9.1 | |
| Yang et al. [35] | 0.5 | 1 | 0.5 | 0.5 | 0 | 1 | 0.9 | 0.9 | 0 | 1 | 1 | 1 | 1 | 9.3 | |

| Table 3. Study and subject characteristics included in the meta-analysis of effects of HIIT on sprint speed/power output for male non-endurance athletes. | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Year** | **Treatment abbreviation** | **Our**  **treatment** | **Type of HIITa** | **Sample size** | **Phase of trainingb** | **Extra trainingc** | **Intervention duration (wk)** | **Pre-test time**  **(s)** | **Effect (%)**  **Mean; 90% CL** |
| Akdoğan et al. [18] | 2021 | CG | Control |  | 9 | 1 | 0 | 6 | 2 | -5.4; -7.3 to -3.6 |
|  |  | CG | Control |  | 9 | 1 | 0 | 6 | 4 | -0.4; -2.4 to 1.5 |
|  |  | CG | Control |  | 9 | 1 | 0 | 6 | 5 | 0.4; -1.5 to 2.4 |
|  |  | SSG | HIIT | 1 | 11 | 1 | 0 | 6 | 2 | -4.0; -5.6 to -2.3 |
|  |  | SER | HIIT | 4 | 10 | 1 | 0 | 6 | 2 | -6.2; -7.9 to -4.5 |
|  |  | SSG | HIIT | 1 | 11 | 1 | 0 | 6 | 4 | -0.5; -2.1 to 1.3 |
|  |  | SER | HIIT | 4 | 10 | 1 | 0 | 6 | 4 | -3.4; -5.1 to -1.6 |
|  |  | SSG | HIIT | 1 | 11 | 1 | 0 | 6 | 5 | 0.8; -0.9 to 2.5 |
|  |  | SER | HIIT | 4 | 10 | 1 | 0 | 6 | 5 | -0.2; -2.0 to 1.6 |
| Chtara et al. [20] | 2017 | CON single | Control |  | 10 | 0 | 0 | 6 | 5 | 1.3; -0.5 to 3.2 |
|  |  | CON best | Control |  | 10 | 0 | 0 | 6 | 6 | 0.0; -1.8 to 1.8 |
|  |  | RS single | HIIT | 5 | 12 | 0 | 0 | 6 | 5 | 1.5; -0.1 to 3.2 |
| Chtara et al. [20] | 2017 | RS best | HIIT | 5 | 12 | 0 | 0 | 6 | 6 | 1.8; 0.1 to 3.4 |
| Dupont et al. [21] | 2004 | Con | Control |  | 22 | 0 | 0 | 10 | 6 | 0.2; -1.0 to 1.3 |
|  |  | Exp | HIIT | 3.5 | 22 | 0 | 0 | 10 | 6 | 3.7; 2.0 to 5.5 |
| Helgerud et al. [22] | 2001 | CON | Control |  | 10 | 0 | 0 | 8 | 2 | 0.0; -1.8 to 1.8 |
|  |  | CON | Control |  | 10 | 0 | 0 | 8 | 6 | -0.2; -2.0 to 1.7 |
|  |  | HIIT | HIIT | 1 | 9 | 0 | 0 | 8 | 2 | 0.5; -1.4 to 2.5 |
|  |  | HIIT | HIIT | 1 | 9 | 0 | 0 | 8 | 6 | 0.4; -1.6 to 2.3 |
| Hermassi et al. [23] | 2018 | Control | Control |  | 15 | 0 | 0 | 7 | 6 | 0.7; -0.8 to 2.1 |
|  |  | Intervention | HIIT | 4 | 15 | 0 | 1 | 7 | 6 | 3.0; 1.5 to 4.4 |
| Iaia et al. [24] | 2015 | SEP | HIIT | 4 | 6 | 0 | 0 | 3 | 3 | 0.4; -1.7 to 2.5 |
|  |  | SEM | HIIT | 3 | 7 | 0 | 0 | 3 | 3 | 1.4; -0.2 to 3.0 |
|  |  | SEP | HIIT | 4 | 6 | 0 | 0 | 3 | 5 | -0.4; -1.8 to 1.1 |
|  |  | SEM | HIIT | 3 | 7 | 0 | 0 | 3 | 5 | 0.8; -0.9 to 2.5 |
|  |  | SEP | HIIT | 4 | 6 | 0 | 0 | 3 | 26 | 1.2; 0.7 to 1.7 |
|  |  | SEM | HIIT | 3 | 7 | 0 | 0 | 3 | 27 | 2.2; 0.1 to 4.3 |
| Selmi et al. [27] | 2018 | Con-G | Control |  | 15 | 0 | 0 | 6 | 8 | -0.8; -1.9 to 0.4 |
|  |  | RST-G | HIIT | 5 | 15 | 0 | 0 | 6 | 8 | 4.4; 2.7 to 6.2 |
| Soares-Caldeira et al. [31] | 2014 | NormT | Control |  | 7 | 1 | 0 | 4 | 7 | 0.1; -1.6 to 1.9 |
|  |  | AddT | HIIT | 5 | 6 | 1 | 1 | 4 | 7 | 1.4; 0.1 to 2.7 |
| Thomassen et al. [32] | 2010 | In | Control |  | 11 | 1 | 0 | 2 | 3 | 0.0; -1.7 to 1.7 |
|  |  | HI | HIIT | 2.5 | 7 | 1 | 0 | 2 | 3 | 0.0; -2.3 to 2.3 |
| Venturelli et al. [33] | 2008 | STG | HIIT | 6 | 7 | 0 | 0 | 12 | 4 | 2.5; 0.3 to 4.7 |
| **Excluded studies** | | | | | | | | | | | |
| Sheykhlouvand et al. [28] | 2016 | Gcon | Control |  | 7 | 1 | 0 | 3 | 5 | 4.7; -0.3 to 9.9 |
|  |  | Gcon | Control |  | 7 | 1 | 0 | 3 | 30 | 3.5; -3.2 to 10.7 |
|  |  | G1 | HIIT | 3 | 7 | 1 | 0 | 3 | 5 | 9.7; 3.5 to 16.3 |
|  |  | G2 | HIIT | 3 | 7 | 1 | 0 | 3 | 5 | 12.2; 4.3 to 20.7 |
|  |  | G1 | HIIT | 3 | 7 | 1 | 0 | 3 | 30 | 10.7; 3.5 to 18.4 |
|  |  | G2 | HIIT | 3 | 7 | 1 | 0 | 3 | 30 | 16.1; 8.6 to 24.2 |
| Sheykhlouvand et al. [29] | 2018 | Control | Control |  | 7 | 1 | 0 | 4 | 5 | 0.5; -5.4 to 6.8 |
|  |  | Control | Control |  | 8 | 1 | 00 | 4 | 30 | 0.3; -5.6 to 6.7 |
|  |  | SIT | HIIT | 5 | 8 | 1 | 0 | 4 | 5 | 9.5; 1.8 to 17.7 |
|  |  | SIT | HIIT | 5 | 8 | 1 | 0 | 4 | 30 | 3.8; -2.3 to 10.4 |
| Yang et al. [35] | 2017 | HIIT | HIIT | 1.5 | 7 | 1 | 0 | 4 | 49 | 3.8; 1.8 to 5.8 |
|  |  | HIIT | HIIT | 1.5 | 7 | 1 | 0 | 4 | 138 | 1.8; -0.2 to 3.8 |
|  |  | HIIT | HIIT | 1.5 | 7 | 1 | 0 | 4 | 296 | 3.6; 1.6 to 5.7 |
| CI, confidence intervals.  Excluded studies: none.  a Range of 1 (aerobic traditional long intervals) to 6 (anaerobic sprint intervals), as presented in Figure 1 in Stöggl et al. [38]  b 0, during the competition phase; 1, outside the competition phase; 0.5, mixture of competition and pre- or post-competition phase. Missing values were imputed to the mean of eligible study estimates (shown in parentheses).  c 0, HIIT partly or entirely replaced regular training; 1, HIIT was added to regular training. | | | | | | | | | | | |

| Table 4. Study and subject characteristics included in the meta-analysis of effects of HIIT on repeated-sprint ability (mean sprint speed/power) for non-endurance trained athletes. | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Year** | **Treatment**  **abbreviation** | **Our treatment** | **Type of HIITa** | **Sample size** | **Maleness** | **Phase of trainingb** | **Extra trainingc** | **Intervention duration (wk)** | **Pre-test decrement (%)** | **Effect (%)**  **Mean; 90% CL** |
| Akdoğan et al. [18] | 2021 | CG | Control |  | 9 | 1 | 1 | 0 | 6 | 5.5 | 0.2; -0.9 to 1.4 |
|  |  | SSG | HIIT | 1 | 11 | 1 | 1 | 0 | 6 | 3.2 | 0.6; -0.4 to 1.7 |
|  |  | SER | HIIT | 4 | 10 | 1 | 1 | 0 | 6 | 3.4 | -0.4; -1.5 to 0.7 |
| Chtara et al. [20] | 2017 | CON | Control |  | 10 | 1 | 0 | 0 | 6 | 3.5 | 1.1; -0.1 to 2.3 |
|  |  | RS | HIIT | 5 | 12 | 1 | 0 | 0 | 6 | 3.5 | 1.7; 0.7 to 2.8 |
| Hermassi et al. [23] | 2018 | Control | Control |  | 15 | 1 | 0 | 0 | 7 | 3.8 | -0.3; -1.2 to 0.7 |
|  |  | Intervention | HIIT | 4 | 15 | 1 | 0 | 1 | 7 | 3.7 | 2.7; 1.8 to 3.7 |
| Iaia et al. [24] | 2015 | SEP | HIIT | 4 | 6 | 1 | 0 | 0 | 3 | 5.0 | 2.5; 1.7 to 3.4 |
|  |  | SEM | HIIT | 3 | 7 | 1 | 0 | 0 | 3 | 4.1 | -1.0; -2.0 to 0.0 |
| Purkhús et al. [26] | 2016 | CON | Control |  | 12 | 0 | 0 | 0 | 8 | 5.5 | -0.2; -2.0 to 1.7 |
|  |  | HIIT | HIIT | 4 | 13 | 0 | 0 | 0 | 8 | 7.0 | 4.4; 2.0 to 6.9 |
| Selmi et al. [27] | 2018 | Con-G | Control |  | 15 | 1 | 0 | 0 | 6 | 6.3 | -1.0; -2.1 to 0.2 |
|  |  | RST-G | HIIT | 5 | 15 | 1 | 0 | 0 | 6 | 6.0 | 5.5; 3.5 to 7.6 |
| Soares-Caldeira et al. [31] | 2014 | NormT | Control |  | 7 | 1 | 1 | 0 | 4 | 7.8 | 2.9; 1.9 to 3.9 |
|  |  | AddT | HIIT | 5 | 6 | 1 | 1 | 0 | 4 | 6.3 | 2.6; 1.6 to 3.5 |
| Thomassen et al. [32] | 2010 | In | Control |  | 11 | 1 | 1 | 0 | 2 | 6.1 | -2.1; -3.0 to -1.2 |
|  |  | HI | HIIT | 3 | 7 | 1 | 1 | 0 | 2 | 5.2 | 1.9; 0.4 to 3.5 |
| CI, confidence intervals.  Excluded studies: none.  a Range of 1 (aerobic traditional long intervals) to 6 (anaerobic sprint intervals), as presented in Figure 1 in Stöggl et al. [38]  b 0, during the competition phase; 1, outside the competition phase; 0.5, mixture of competition and pre- or post-competition phase. Missing values were imputed to the mean of eligible study estimates (shown in parentheses).  c 0, HIIT partly or entirely replaced regular training; 1, HIIT was added to regular training. | | | | | | | | | | | | |

| Table 5. Study and subject characteristics included in the meta-analysis of effects of HIIT on **time-trial speed/power** output for endurance-trained athletes. | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Year** | **Treatment abbreviation** | **Our treatment** | **Type of HIITa** | **Sample size** | **Malenessb** | **Extra trainingc** | **Intervention duration (wk)** | **Pre-test time (min)** | **Effect (%)**  **Mean; 90% CL** |
| Clark et al. [2] | 2014 | Control | Control |  | 9 | 1 | 0 | 1 | 38 | -3.1; -5.9 to -0.3 |
|  |  | Short HIIT | HIIT | 5 | 9 | 1 | 0 | 1 | 38 | 4.3; 2.3 to 6.3 |
|  |  | Long HIIT | HIIT | 4 | 10 | 1 | 0 | 1 | 39 | 6.9; 4.5 to 9.3 |
| Laursen et al. [5] | 2002 | Control | Control |  | 11 | 1 | 0 | 4 | 57 | -2.1; -4.3 to 0.2 |
|  |  | G1 | HIIT | 1 | 8 | 1 | 1 | 4 | 57 | 11.5; 6.6 to 16.6 |
|  |  | G2 | HIIT | 1 | 9 | 1 | 1 | 4 | 58 | 12.2; 8.8 to 15.8 |
|  |  | G3 | HIIT | 4 | 10 | 1 | 1 | 4 | 57 | 9.5; 4.7 to 14.4 |
| Salazar-Martínez et al. [8] | 2018 | Con | Control |  | 8 | 1 | 0 | 3 | 1 | 1.0; -3.4 to 5.6 |
|  |  | HIIT | HIIT | 1 | 8 | 1 | 0 | 3 | 1 | 2.2; 0.3 to 4.2 |
| Skovereng et al. [11] | 2018 | HIIT | HIIT | 1 | 63 | 1 | 1 | 12 | 40 | 6.7; 4.8 to 8.7 |
| Smith et al. [12] | 2003 | CON | Control |  | 9 | (1) | 0 | 4 | 10 | 0.1; -2.2 to 2.4 |
|  |  | CON | Control |  | 9 | (1) | 0 | 4 | 18 | -0.9; -3.1 to 1.3 |
|  |  | 60%Tmax | HIIT | 1 | 9 | (1) | 0 | 4 | 11 | 2.8; 1.8 to 3.9 |
|  |  | 70%Tmax | HIIT | 1 | 9 | (1) | 0 | 4 | 10 | 1.0; -0.2 to 2.3 |
|  |  | 60%Tmax | HIIT | 1 | 9 | (1) | 0 | 4 | 19 | 2.3; 0.1 to 4.7 |
|  |  | 70%Tmax | HIIT | 1 | 9 | (1) | 0 | 4 | 18 | 0.3; -1.6 to 2.3 |
| Stepto et al. [14] | 1999 | HIIT | HIIT | 4 | 11 | 1 | 0 | 3 | 57 | 3.2; 1.0 to 5.4 |
| Stevens et al. [15] | 2015 | EBTAlone | Control |  | 8 | (1) | 0 | 4 | 7 | 1.2; 0.5 to 1.8 |
|  |  | EBTSIT | HIIT | 4 | 8 | (1) | 0 | 4 | 7 | 2.9; 2.0 to 3.8 |
| Sylta et al. [17] | 2016 | INC | HIIT | 1 | 23 | 1 | 0 | 12 | 40 | 8.2; 5.4 to 11.0 |
|  |  | DEC | HIIT | 1 | 20 | 1 | 0 | 12 | 40 | 6.8; 4.2 to 9.5 |
|  |  | MIX | HIIT | 1 | 20 | 1 | 0 | 12 | 40 | 3.5; 1.7 to 5.3 |
|  |  | INC | HIIT | 1 | 23 | 1 | 0 | 12 | 0.5 | 1.2; -0.4 to 2.7 |
|  |  | DEC | HIIT | 1 | 20 | 1 | 0 | 12 | 0.5 | 2.4; 0.8 to 4.1 |
|  |  | MIX | HIIT | 1 | 20 | 1 | 0 | 12 | 0.5 | 2.2; 0.4 to 4.0 |
| **Excluded studies** | | | | | | | | | | |
| Sandbakk et al. [9] | 2011 | CON | Control |  | 8 | 0.33 | 0 | 8 | 4 | -0.9; -2.2 to 0.4 |
|  |  | IG | HIIT | 1 | 7 | 0.33 | 0 | 8 | 4 | 4.7; 2.4 to 7.1 |
| Sandbakk et al. [10] | 2013 | CON | Control |  | 7 | 0.57 | 1 | 8 | 32 | 1.0; -0.3 to 2.4 |
|  |  | CON | Control |  | 7 | 0.57 | 1 | 8 | 35 | 1.0; -1.5 to 3.5 |
|  |  | SIG | HIIT | 1 | 7 | 0.57 | 1 | 8 | 33 | 1.6; -0.1 to 3.2 |
|  |  | LIG | HIIT | 1 | 7 | 0.57 | 1 | 8 | 33 | 4.7; 2.8 to 6.7 |
| Sandbakk et al. [10] | 2013 | SIG | HIIT | 1 | 7 | 0.57 | 1 | 8 | 37 | 0.9; -1.5 to 3.4 |
|  |  | LIG | HIIT | 1 | 7 | 0.57 | 1 | 8 | 37 | 6.8; 3.8 to 10.0 |
| Stevens et al. [15] | 2015 | EBTAlone | Control |  | 8 | (1) | 0 | 4 | 1 | 0.4; -1.4 to 2.2 |
|  |  | EBTSIT | HIIT | 4 | 8 | (1) | 0 | 4 | 1 | 4.4; 1.1 to 7.8 |
| CI, confidence intervals.  Excluded studies: none.  a Range of 1 (aerobic traditional long intervals) to 6 (anaerobic sprint intervals), as presented in Figure 1 in Stöggl et al. [38]  b Proportion of males; missing values were imputed to 1 (shown in parentheses).  c 0, during the competition phase; 1, outside the competition phase; 0.5, mixture of competition and pre- or post-competition phase. Missing values were imputed to the mean of eligible study estimates (shown in parentheses).  c 0, HIIT partly or entirely replaced regular training; 1, HIIT was added to regular training. | | | | | | | | | | | |

| Table 6. Study and subject characteristics included and excluded in the meta-analysis of effects of HIIT on peak speed/power in an incremental test for male athletes. | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Year** | **Type of athlete** | **Treatment abbreviation** | **Our treatment** | **Type of test** | **Protocol** | **Type of HIITa** | **Sample size** | **Phase of trainingb** | **Extra trainingc** | **Intervention duration (wk)** | **Adjusted test duration (min)** | **Effect (%)**  **Mean; 90% CL** |
| Akdoğan et al.[18] | 2021 | Other | CG | Control | Yoyo | Yoyo IR1 |  | 9 | 1 | 0 | 6 | 8 | 0.4; -0.7 to 1.5 |
|  |  | Other | CG | Control | Yoyo | Yoyo IR2 |  | 9 | 1 | 0 | 6 | 4 | 0.1; -1.2 to 1.4 |
|  |  | Other | SSG | HIIT | Yoyo | Yoyo IR1 | 1 | 11 | 1 | 0 | 6 | 11 | 2.6; 1.4 to 3.7 |
|  |  | Other | SER | HIIT | Yoyo | Yoyo IR1 | 4 | 10 | 1 | 0 | 6 | 11 | 3.2; 2.2 to 4.3 |
|  |  | Other | SSG | HIIT | Yoyo | Yoyo IR2 | 1 | 11 | 1 | 0 | 6 | 4 | 2.1; 1.0 to 3.3 |
|  |  | Other | SER | HIIT | Yoyo | Yoyo IR2 | 4 | 10 | 1 | 0 | 6 | 4 | 2.3; 1.1 to 3.5 |
| Clark et al. [2] | 2014 | Endurance | Control | Control | Incr. | CycleIncr. |  | 9 | 0 | 0 | 1 | 18 | -1.8; -3.5 to 0.0 |
|  |  | Endurance | Short HIIT | HIIT | Incr. | CycleIncr. | 5 | 9 | 0 | 0 | 1 | 19 | 7.6; 3.6 to 11.7 |
|  |  | Endurance | Long HIIT | HIIT | Incr. | CycleIncr. | 4 | 10 | 0 | 0 | 1 | 19 | 3.6; 2.9 to 4.2 |
| Iaia et al. [24] | 2015 | Other | SEP | HIIT | Yoyo | Yoyo IR2 | 4 | 6 | 0 | 0 | 3 | 7 | 0.8; 0.4 to 1.2 |
|  |  | Other | SEM | HIIT | Yoyo | Yoyo IR2 | 3 | 7 | 0 | 0 | 3 | 7 | 0.3; -0.1 to 0.7 |
| Laursen et al. [5] | 2002 | Endurance | Control | Control | Incr. | CycleIncr. |  | 11 | 1 | 0 | 4 | 7 | -0.9; -1.8 to -0.1 |
|  |  | Endurance | G1 | HIIT | Incr. | CycleIncr. | 1 | 8 | 1 | 1 | 4 | 7 | 4.8; 2.8 to 6.8 |
|  |  | Endurance | G2 | HIIT | Incr. | CycleIncr. | 1 | 9 | 1 | 1 | 4 | 7 | 6.0; 4.3 to 7.8 |
|  |  | Endurance | G3 | HIIT | Incr. | CycleIncr. | 4 | 10 | 1 | 1 | 4 | 7 | 3.1; 1.3 to 4.8 |
| Liu et al. [25] | 2021 | Other | CON male | Control | Yoyo | Yoyo IR2 |  | 8 | 0 | 0 | 8 | 7 | 0.4; -0.6 to 1.4 |
|  |  | Other | SIT male | HIIT | Yoyo | Yoyo IR2 | 4 | 8 | 0 | 0 | 8 | 8 | 1.1; 0.1 to 2.1 |
| Rønnestad et al. [7] | 2019 | Endurance | Exp | HIIT | Incr. | CycleIncr. | 3 | 9 | 0 | 1 | 0.9 | 7 | 5.0; 2.4 to 7.6 |
| Skovereng et al. [11] | 2018 | Endurance | HIIT | HIIT | Incr. | CycleIncr. | 1 | 63 | 1 | 1 | 12 | 5 | 3.2; 1.6 to 4.9 |
| Soares-Caldeira et al. [31] | 2014 | Other | NormT | Control | Yoyo | Yoyo IR1 |  | 7 | 1 | 0 | 4 | 10 | 2.9; 1.6 to 4.3 |
|  |  | Other | AddT | HIIT | Yoyo | Yoyo IR1 | 5 | 6 | 1 | 1 | 4 | 10 | 3.7; 2.0 to 5.4 |
| Stepto et al. [14] | 1999 | Endurance | HIIT | HIIT | Incr. | CycleIncr. | 4 | 11 | 0 | 0 | 3 | 12 | 1.1; 0.5 to 1.8 |
| Stöggl et al. [16] | 2014 | Endurance | HVTcyc | Control | Incr. | CycleIncr. |  | 3 | 0.5 | 0 | 9 | 3 | 2.5; 0.5 to 4.5 |
|  |  | Endurance | HVTrun | Control | Incr. | RunIncr. |  | 5 | 0.5 | 0 | 9 | 4 | 5.6; 0.8 to 10.7 |
|  |  | Endurance | HIIT | HIIT | Incr. | CycleIncr. | 1 | 9 | 0.5 | 0 | 9 | 4 | 3.9; 1.8 to 6.1 |
|  |  | Endurance | POLcyc | HIIT | Incr. | CycleIncr. | 1 | 6 | 0.5 | 0 | 9 | 3 | 5.7; 2.8 to 8.6 |
| Sylta et al. [17] | 2016 | Endurance | INC | HIIT | Incr. | CycleIncr. | 1 | 23 | 1 | 0 | 12 | 6 | 4.6; 2.3 to 6.8 |
|  |  | Endurance | DEC | HIIT | Incr. | CycleIncr. | 1 | 20 | 1 | 0 | 12 | 6 | 5.3; 3.6 to 7.1 |
|  |  | Endurance | MIX | HIIT | Incr. | CycleIncr. | 1 | 20 | 1 | 0 | 12 | 6 | 6.1; 3.5 to 8.7 |
| Thomassen et al. [32] | 2010 | Other | In | Control | Yoyo | Yoyo IR2 |  | 11 | 1 | 0 | 2 | 6 | -0.4; -0.5 to -0.2 |
|  |  | Other | HI | HIIT | Yoyo | Yoyo IR2 | 3 | 7 | 1 | 0 | 2 | 7 | 0.5; -0.2 to 1.2 |
| Wells et al. [34] | 2014 | Other | CON | Control | Incr. | RunIncr. |  | 8 | 0 | 0 | 6 | 8 | -2.1; -3.2 to -1.0 |
| Wells et al. [34] | 2014 | Other | CON MART | Control | Incr. | RunIncr. |  | 8 | 0 | 0 | 6 | 2 | 1.3; -2.4 to 5.3 |
|  |  | Other | TRA | HIIT | Incr. | RunIncr. | 4 | 8 | 0 | 0 | 6 | 8 | -0.5; -1.5 to 0.5 |
|  |  | Other | TRA MART | HIIT | Incr. | RunIncr. | 4 | 8 | 0 | 0 | 6 | 2 | 9.8; 3.2 to 16.9 |
| **Excluded studies** | | | | | | | | | | | | | | | |
| Hermassi et al. [23] | 2018 | Other | Control | Control | Yoyo | Yoyo IR2 |  | 15 | 0 | 0 | 7 | 4 | -2.9; -3.6 to -2.2 |
|  |  | Other | Intervention | HIIT | Yoyo | Yoyo IR2 | 4 | 15 | 0 | 1 | 7 | 4 | 25.9; 25.0 to 26.8 |
| Sarkar et al. [37] | 2021 | Other | Control | Control | Incr. | CycleIncr. |  | 20 |  | 0 | 8 |  | -0.9; -2.1 to 0.3 |
|  |  | Other | HIIT | HIIT | Incr. | CycleIncr. | n.i. | 20 |  | 0 | 8 |  | 11.6; 6.2 to 17.2 |
| CI, confidence intervals; Incr., incremental test; Yoyo IR1, Yoyo intermittent recovery test level 1; Yoyo IR2, Yoyo intermittent recovery test level 2.  Excluded studies: The outcome measure in Hermassi et al. [23] was an extreme outlier, Sarkar et al. [37], did not have clear information about testing.  a Range of 1 (aerobic traditional long intervals) to 6 (anaerobic sprint intervals), as presented in Figure 1 in Stöggl et al. [38]  b 0, during the competition phase; 1, outside the competition phase; 0.5, mixture of competition and pre- or post-competition phase. Missing values were imputed to the mean of eligible study estimates (shown in parentheses).  c 0, HIIT partly or entirely replaced regular training; 1, HIIT was added to regular training. | | | | | | | | | | | | | | | |

| Table 7. Study and subject characteristics included in the meta-analysis of effects of HIIT on aerobic/anaerobic threshold for non-endurance trained athletes. | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Year** | **Type of athlete** | **Treatment abbreviation** | **Our treatment** | **Type of HIITa** | **Sample size** | **Maleness** | **Phase of trainingb** | **Extra trainingc** | **Intervention duration (wk)** | **Threshold pred** | **Effect (%)**  **Mean; 90% CL** |
| Breil et al. [19] | 2010 | Other | CT | Control |  | 8 | 0.75 | -1 | 0 | 2 | 53.6 | 0.7; -6.2 to 8.2 |
|  |  | Other | CT | Control |  | 8 | 0.75 | -1 | 0 | 2 | 84.5 | 1.2; -2.8 to 5.5 |
|  |  | Other | IT | HIIT | 1 | 13 | 0.69 | -1 | 0 | 2 | 57.8 | 2.1; -3.1 to 7.6 |
| Breil et al. [19] | 2010 | Other | IT | HIIT | 1 | 13 | 0.69 | -1 | 0 | 2 | 85.3 | 9.8; 6.6 to 13.2 |
| Clark et al. [2] | 2014 | Endurance | Control | Control |  | 9 | 1 | 0 | 0 | 1 | 84.6 | -3.4; -7.1 to 0.4 |
|  |  | Endurance | Short HIIT | HIIT | 5 | 9 | 1 | 0 | 0 | 1 | 78.9 | 3.8; 1.6 to 6.0 |
|  |  | Endurance | Long HIIT | HIIT | 4 | 10 | 1 | 0 | 0 | 1 | 87.3 | 2.7; -0.4 to 5.8 |
| Helgerud et al. [22] | 2001 | Other | CON | Control |  | 10 | 1 | 0 | 1 | 8 | 86.2 | -1.7; -7.6 to 4.5 |
|  |  | Other | HIIT | HIIT | 1 | 9 | 1 | 0 | 1 | 8 | 87.4 | 5.4; -1.3 to 12.6 |
| Rønnestad et al. [7] | 2019 | Endurance | Exp | HIIT | 3 | 9 | 1 | 0 | 1 | 0.9 | 69.5 | 3.9; 2.0 to 5.9 |
| Sandbakk et al. [9] | 2011 | Endurance | CON | Control |  | 8 | 0.33 | -1 | 0 | 8 | 80.9 | 0.0; -4.0 to 4.2 |
|  |  | Endurance | IG | HIIT | 1 | 7 | 0.33 | -1 | 0 | 8 | 77.2 | 9.8; 6.4 to 13.3 |
| Sandbakk et al. [10] | 2013 | Endurance | CON | Control |  | 7 | 0.57 | -1 | 1 | 8 | 79.0 | 1.2; -3.2 to 5.9 |
|  |  | Endurance | SIG | HIIT | 1 | 7 | 0.57 | -1 | 1 | 8 | 78.9 | 1.6; -2.8 to 6.3 |
|  |  | Endurance | LIG | HIIT | 1 | 7 | 0.57 | -1 | 1 | 8 | 77.0 | 9.8; 5.0 to 14.9 |
| Sheykhlouvand et al. [29] | 2018 | Other | Control | Control |  | 8 | 0 | -1 | 0 | 4 | 73.1 | 1.5; -2.5 to 5.8 |
|  |  | Other | SIT | HIIT | 5 | 8 | 0 | -1 | 0 | 4 | 77.7 | 7.5; 3.2 to 12.0 |
| Smith et al. [12] | 2003 | Endurance | CON | Control |  | 9 | (1) | . | 0 | 4 | 76.7 | 2.9; -0.9 to 6.9 |
|  |  | Endurance | 60%Tmax | HIIT | 1 | 9 | (1) | . | 0 | 4 | 73.5 | 15.7; 11.4 to 20.1 |
|  |  | Endurance | 70%Tmax | HIIT | 1 | 9 | (1) | . | 0 | 4 | 78.4 | 6.4; 2.5 to 10.5 |
| Stevens et al. [15] | 2015 | Endurance | EBTAlone | Control |  | 8 | 1 | -1 | 0 | 4 | 81.0 | 1.6; -5.4 to 9.1 |
|  |  | Endurance | EBTSIT | HIIT | 4 | 8 | 1 | -1 | 0 | 4 | 83.0 | -1.5; -8.3 to 5.7 |
| Stöggl et al. [16] | 2014 | Endurance | HVTcyc | Control |  | 3 | 1 | -0.5 | 0 | 9 | 59.6 | 4.0; -15.8 to 28.5 |
|  |  | Endurance | HVTrun | Control |  | 5 | 1 | -0.5 | 0 | 9 | 65.5 | -1.4; -15.6 to 15.1 |
|  |  | Endurance | HVTrun | Control |  | 5 | 1 | -0.5 | 0 | 9 | 82.9 | 1.8; -4.6 to 8.7 |
|  |  | Endurance | HVTcyc | Control |  | 3 | 1 | -0.5 | 0 | 9 | 80.0 | 0.1; -12.6 to 14.6 |
|  |  | Endurance | HIIT | HIIT | 1 | 9 | 1 | -0.5 | 0 | 9 | 51.0 | 11.3; 6.4 to 16.3 |
|  |  | Endurance | POLcyc | HIIT | 1 | 4 | 1 | -0.5 | 0 | 9 | 56.1 | 2.7; -9.3 to 16.3 |
|  |  | Endurance | POLrun | HIIT | 1 | 7 | 0.86 | -0.5 | 0 | 9 | 59.0 | 9.8; 3.2 to 16.9 |
|  |  | Endurance | HIIT | HIIT | 1 | 9 | 1 | -0.5 | 0 | 9 | 75.4 | 5.2; 2.4 to 8.1 |
|  |  | Endurance | POLrun | HIIT | 1 | 7 | 0.86 | -0.5 | 0 | 9 | 79.2 | 8.4; 4.6 to 12.4 |
|  |  | Endurance | POLcyc | HIIT | 1 | 4 | 1 | -0.5 | 0 | 9 | 79.3 | 6.6; 5.4 to 7.9 |
| Sylta et al. [17] | 2016 | Endurance | INC | HIIT | 1 | 23 | 1 | -1 | 0 | 12 | 77.3 | 5.1; 2.2 to 8.0 |
|  |  | Endurance | DEC | HIIT | 1 | 20 | 1 | -1 | 0 | 12 | 79.4 | 0.8; -1.7 to 3.4 |
|  |  | Endurance | MIX | HIIT | 1 | 20 | 1 | -1 | 0 | 12 | 80.7 | 3.3; 0.5 to 6.1 |
| CI, confidence intervals.  Excluded studies: none.  a Range of 1 (aerobic traditional long intervals) to 6 (anaerobic sprint intervals), as presented in Figure 1 in Stöggl et al. [38]  b 0, during the competition phase; 1, outside the competition phase; 0.5, mixture of competition and pre- or post-competition phase. Missing values were imputed to the mean of eligible study estimates (shown in parentheses).  c 0, HIIT partly or entirely replaced regular training; 1, HIIT was added to regular training.  d Threshold as a percentage of V̇O2max. | | | | | | | | | | | | | |

| Table 8. Study and subject characteristics included and excluded in the meta-analysis of effects of HIIT on **V̇O2max**. | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Year** | **Type of athlete** | **Authors’ treatment abbreviation** | **Our treatment** | **Type of HIITa** | **Sample size** | **Malenessb** | **Phase of trainingc** | **Extra trainingd** | **Intervention duration (wk)** | **V̇O2max pre**  **Mean ± SD** | **Effect (%)**  **Mean; 90% CL** |
| Breil et al. [19] | 2010 | Other | CT | Control |  | 8 | 0.75 | 1 | 0 | 2 | 52.9 ± 6.3 | 2.8; -0.4 to 6.2 |
|  |  | Other | IT | HIIT | 1 | 13 | 0.69 | 1 | 0 | 2 | 53.0 ± 4.6 | 6.0; 4.2 to 7.9 |
| Clark et al. [2] | 2014 | Endurance | Control | Control |  | 9 | 1 | 0 | 0 | 1 | 61.2 ± 10.0 | -0.8; -4.2 to 2.7 |
|  |  | Endurance | Short HIIT | HIIT | 5 | 9 | 1 | 0 | 0 | 1 | 65.4 ± 4.7 | 2.2; -0.7 to 5.2 |
|  |  | Endurance | Long HIIT | HIIT | 4 | 10 | 1 | 0 | 0 | 1 | 62.8 ± 5.2 | 3.7; 0.3 to 7.3 |
| Hanstock et al. [3] | 2020 | Endurance | Si1 | HIIT | 3 | 9 | 1 | 1 | 0 | 4 | 63.5 ± 5.6 | 3.6; 1.6 to 5.7 |
|  |  | Endurance | Si2 | HIIT | 3 | 9 | 1 | 1 | 0 | 4 | 64.5 ± 7.3 | 0.3; -0.6 to 1.2 |
| Helgerud et al. [22] | 2001 | Other | CON | Control |  | 10 | 1 | 0 | 1 | 8 | 58.4 ± 4.3 | 1.9; -0.9 to 4.7 |
|  |  | Other | HIIT | HIIT | 1 | 9 | 1 | 0 | 1 | 8 | 58.1 ± 4.5 | 10.7; 7.7 to 13.7 |
| Johansen et al. [4] | 2021 | Endurance | CON | Control |  | 7 | (1) | 1 | 0 | 6 | 71.6 ± 3.9 | -0.6; -3.5 to 2.5 |
|  |  | Endurance | HIIT | HIIT | 1 | 7 | (1) | 1 | 0 | 6 | 65.8 ± 10.9 | -3.8; -7.1 to -0.4 |
| Laursen et al. [5] | 2002 | Endurance | Control | Control |  | 11 | 1 | 1 | 0 | 4 | 65.2 ± 5.9 | 0.8; -0.9 to 2.6 |
|  |  | Endurance | G1 | HIIT | 1 | 8 | 1 | 1 | 1 | 4 | 66.5 ± 6.2 | 5.2; 2.9 to 7.6 |
| Laursen et al. [5] | 2002 | Endurance | G2 | HIIT | 1 | 9 | 1 | 1 | 1 | 4 | 63.7 ± 4.1 | 8.0; 6.0 to 10.0 |
|  |  | Endurance | G3 | HIIT | 4 | 10 | 1 | 1 | 1 | 4 | 62.6 ± 4.1 | 3.1; 1.4 to 4.8 |
| Liu et al. [25] | 2021 | Other | CON male | Control |  | 8 | 1 | 0 | 0 | 8 | 55.8 ± 8.0 | 3.4; 0.2 to 6.8 |
|  |  | Other | CON female | Control |  | 8 | 0 | 0 | 0 | 8 | 42.9 ± 1.6 | 0.9; -2.2 to 4.2 |
|  |  | Other | SIT male | HIIT | 4 | 8 | 1 | 0 | 0 | 8 | 56.8 ± 7.0 | 12.0; 8.8 to 15.3 |
|  |  | Other | SIT female | HIIT | 4 | 8 | 0 | 0 | 0 | 8 | 42.5 ± 2.9 | 8.7; 5.6 to 11.9 |
| Menz et al. [6] | 2015 | Endurance | HIIT | HIIT | 1 | 19 | 0.74 | 1 | 0 | 3 | 63.6 ± 7.5 | 3.5; 1.3 to 5.6 |
| Rønnestad et al. [7] | 2019 | Endurance | Exp | HIIT | 3 | 9 | 1 | 0 | 1 | 0.9 | 76.8 ± 6.9 | 3.8; 2.1 to 5.5 |
| Salazar-Martínez et al. [8] | 2018 | Endurance | Con | Control |  | 8 | 1 | 1 | 0 | 3 | 67.0 ± 6.5 | -0.3; -3.6 to 3.1 |
|  |  | Endurance | HIIT | HIIT | 1 | 8 | 1 | 1 | 0 | 3 | 68.4 ± 2.7 | 2.0; -0.9 to 5.1 |
| Sandbakk et al. [9] | 2011 | Endurance | CON | Control |  | 8 | 0.33 | 1 | 0 | 8 | 69.3 ± 7.2 | 1.4; -2.2 to 5.2 |
|  |  | Endurance | IG | HIIT | 1 | 7 | 0.33 | 1 | 0 | 8 | 67.5 ± 6.5 | 4.0; 2.5 to 5.6 |
| Sandbakk et al. [10] | 2013 | Endurance | CON | Control |  | 7 | 0.57 | 1 | 1 | 8 | 68.0 ± 7.0 | 0.0; -2.7 to 2.8 |
|  |  | Endurance | SIG | HIIT | 1 | 7 | 0.57 | 1 | 1 | 8 | 67.0 ± 8.0 | 3.0; 0.6 to 5.4 |
|  |  | Endurance | LIG | HIIT | 1 | 7 | 0.57 | 1 | 1 | 8 | 67.0 ± 6.0 | 4.5; 3.3 to 5.7 |
| Sheykhlouvand et al. [28] | 2016 | Other | Gcon | Control |  | 7 | (1) | 1 | 0 | 3 | 37.1 ± 5.7 | 2.2; -1.8 to 6.3 |
|  |  | Other | G1 | HIIT | 3 | 7 | (1) | 1 | 0 | 3 | 39.2 ± 4.1 | 6.6; 3.0 to 10.3 |
|  |  | Other | G2 | HIIT | 3 | 7 | (1) | 1 | 0 | 3 | 37.8 ± 4.6 | 7.7; 2.8 to 12.8 |
| Sheykhlouvand et al. [29] | 2018 | Other | Control | Control |  | 8 | 0 | 1 | 0 | 4 | 39.2 ± 4.1 | 1.5; 0.0 to 3.1 |
| Sheykhlouvand et al. [29] | 2018 | Other | SIT | HIIT | 5 | 8 | 0 | 1 | 0 | 4 | 37.1 ± 3.5 | 7.5; 3.3 to 11.9 |
| Skovereng et al. [11] | 2018 | Endurance | HIIT | HIIT | 1 | 60 | 1 | 1 | 1 | 12 | 61.0 ± 6.0 | 6.6; 5.9 to 7.2 |
| Smith et al. [12] | 2003 | Endurance | CON | Control |  | 9 | (1) | (0.68) | 0 | 4 | 63.6 ± 6.0 | 0.6; -2.3 to 3.6 |
|  |  | Endurance | 60%Tmax | HIIT | 1 | 9 | (1) | (0.68) | 0 | 4 | 60.5 ± 5.7 | 6.0; 3.1 to 8.8 |
|  |  | Endurance | 70%Tmax | HIIT | 1 | 9 | (1) | (0.68) | 0 | 4 | 60.1 ± 1.8 | 4.2; 1.4 to 7.0 |
| Stenqvist et al. [13] | 2020 | Endurance | HIIT | HIIT | 2 | 22 | (1) | 1 | 0 | 4 | 63.5 ± 6.6 | 2.4; 1.1 to 3.7 |
| Stevens et al. [15] | 2015 | Endurance | EBTAlone | Control |  | 8 | (1) | 1 | 0 | 4 | 63.3 ± 6.2 | -1.7; -4.8 to 1.5 |
|  |  | Endurance | EBTSIT | HIIT | 4 | 8 | (1) | 1 | 0 | 4 | 61.4 ± 7.4 | 0.0; -2.9 to 3.0 |
| Stöggl et al. [16] | 2014 | Endurance | HVTcyc | Control |  | 3 | 1 | 0.5 | 0 | 9 | 55.8 ± 4.2 | 3.4; -0.4 to 7.4 |
|  |  | Endurance | HVTrun | Control |  | 5 | 1 | 0.5 | 0 | 9 | 63.4 ± 10.9 | 2.0; -3.4 to 7.7 |
|  |  | Endurance | HIIT | HIIT | 1 | 9 | 1 | 0.5 | 0 | 9 | 63.7 ± 7.1 | 4.5; 1.0 to 8.0 |
|  |  | Endurance | POLcyc | HIIT | 1 | 7 | 1 | 0.5 | 0 | 9 | 61.5 ± 8.3 | 11.6; 5.5 to 18.1 |
|  |  | Endurance | POLrun | HIIT | 1 | 4 | 0.75 | 0.5 | 0 | 9 | 59.1 ± 9.3 | 10.3; 6.4 to 14.4 |
| Sylta et al. [17] | 2016 | Endurance | INC | HIIT | 1 | 23 | 1 | 1 | 0 | 12 | 61.8 ± 5.4 | 7.8; 5.9 to 9.6 |
|  |  | Endurance | DEC | HIIT | 1 | 20 | 1 | 1 | 0 | 12 | 60.6 ± 4.1 | 5.8; 3.9 to 7.6 |
|  |  | Endurance | MIX | HIIT | 1 | 20 | 1 | 1 | 0 | 12 | 61.6 ± 3.8 | 4.9; 3.1 to 6.7 |
| Wells et al. [34] | 2014 | Other | CON | Control |  | 8 | 1 | 0 | 0 | 6 | 57.1 ± 3.6 | 0.9; -3.7 to 5.6 |
|  |  | Other | TRA | HIIT | 4 | 8 | 1 | 0 | 0 | 6 | 57.6 ± 5.4 | 2.3; -4.5 to 9.5 |
| Yang et al. [35] | 2017 | Other | HIIT | HIIT | 2 | 7 | 1 | 1 | 0 | 4 | 45.9 ± 7.2 | 6.5; 3.1 to 10.1 |
| **Excluded studies** | | | | | | | | | | | | | |
| Sheykhlouvand et al. [30] | 2018 | Other | CET | Control |  | 7 | 1 | 1 | 0 | 3 | 37.1 ± 5,7 | 2.2; -1.8 to 6.3 |
|  |  | Other | VVHIIT | HIIT | 3 | 7 | 1 | 1 | 0 | 3 | 39.2 ± 4.1 | 6.6.; 3.0 to 10.3 |
|  |  | Other | VIHIIT | HIIT | 3 | 7 | 1 | 1 | 0 | 3 | 37.8 ± 4.6 | 7.7; 2.8 to 12.8 |
| CI, confidence intervals.  Excluded studies: equal V̇O2max values as in Sheykhlouvand, Khallili [28]  a Range of 1 (aerobic traditional long intervals) to 6 (anaerobic sprint intervals), as presented in Figure 1 in Stöggl et al. [38]  b Proportion of males; missing values were imputed to 1 (shown in parentheses).  c 0, during the competition phase; 1, outside the competition phase; 0.5, mixture of competition and pre- or post-competition phase. Missing values were imputed to the mean of eligible study estimates (shown in parentheses).  d 0, HIIT partly or entirely replaced regular training; 1, HIIT was added to regular training. | | | | | | | | | | | | | |

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| Table 9. Study and subject characteristics included in the meta-analysis of effects of HIIT on **exercise economy** for endurance-trained athletes. | | | | | | | | | | | |
| **Study** | **Year** | **Type of athlete** | **Treatment abbreviation** | **Our treatment** | **Type of HIITa** | **Sample size** | **Maleness** | **Phase of trainingb** | **Intervention duration (wk)** | **Effect (%)**  **Mean; 90% CL** |
| Clark et al. [2] | 2014 | Endurance | Control | Control |  | 9 | 1 | 0 | 1 | 2.2; -0.4 to 4.9 |
|  |  | Other | Short HIIT | HIIT | 5 | 9 | 1 | 0 | 1 | 3.8; 1.1 to 6.5 |
|  |  | Endurance | Long HIIT | HIIT | 4 | 10 | 1 | 0 | 1 | 4.7; 2.5 to 7.0 |
| Helgerud et al. [22] | 2001 | Other | CON | Control |  | 10 | 1 | 0 | 8 | 1.4; -3.3 to 6.3 |
|  |  | Other | HIIT | HIIT | 1 | 9 | 1 | 0 | 8 | 7.1; 1.9 to 12.7 |
| Rønnestad et al. [7] | 2019 | Endurance | Exp | HIIT | 3 | 9 | 1 | 0 | 0.86 | 0.4; -4.9 to 6.0 |
| Skovereng et al. [11] | 2018 | Endurance | HIIT | HIIT | 1 | 60 | 1 | -1 | 12 | -0.4; -1.4 to 0.5 |
| Stöggl et al. [16] | 2014 | Endurance | HVTcyc | Control |  | 3 | 1 | -0.5 | 9 | -0.1; -16.0 to 18.7 |
|  |  | Endurance | HVTrun | Control |  | 5 | 1 | -0.5 | 9 | -0.1; -9.5 to 10.1 |
|  |  | Endurance | HIIT | HIIT | 1 | 9 | 1 | -0.5 | 9 | -3.1; -10.1 to 4.5 |
|  |  | Endurance | POLcyc | HIIT | 1 | 6 | 1 | -0.5 | 9 | -3.9; -11.5 to 4.3 |
| Sylta et al. [17] | 2016 | Endurance | INC | HIIT | 1 | 23 | 1 | -1 | 12 | -0.5; -2.4 to 1.5 |
|  |  | Endurance | DEC | HIIT | 1 | 20 | 1 | -1 | 12 | -0.4; -2.1 to 1.3 |
|  |  | Endurance | MIX | HIIT | 1 | 20 | 1 | -1 | 12 | -0.2; -1.9 to 1.5 |
| Yang et al. [35] | 2017 | Other | HIIT | HIIT | 1.5 | 7 | 1 | -1 | 4 | 3.1; -2.9 to 9.5 |
| **Excluded study estimate** | | | | | | | | | | | | |
| Stöggl et al. [16] | 2014 |  | POLrun | HIIT | 1 | 6 | 0.83 | -0.5 | 9 | -3.9; -11.5 to 4.3 |
| CI, confidence intervals.  Excluded studies: none.  a Range of 1 (aerobic traditional long intervals) to 6 (anaerobic sprint intervals), as presented in Figure 1 in Stöggl et al. [38]  b 0, during the competition phase; 1, outside the competition phase; 0.5, mixture of competition and pre- or post-competition phase. Missing values were imputed to the mean of eligible study estimates (shown in parentheses). | | | | | | | | | | | |

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| Table 10: Summary of Tables 4 to 10 in the original manuscript, including predicted effects, moderator effects, and heterogeneity SDs in the meta-analyses of each performce measure. Error of measurement and individual-responses SDs are also included. The data are effect qualitative magnitude, probability of the magnitude, and the observed quantitative magnitude. | | | | | | | | | | | | | | | | | | | | |
|  | | **Sprint speed/ power** | | **Repeated sprint ability** | | **Time-trial speed/ power** | | **Peak speed/ power** | | **Aerobic/ anaerobic threshold** | | | **V̇O2max** | | | | **Exercise economy** | | | |
| ***Predicted effects*** | | **a** | | **b** | | **c** | | **d** | | **e** | | | **f** | | | | **g** | | | |
| **Endurance athletes** | |  | |  | |  | |  | |  | | |  | | | |  | | | |
|  | Males HIIT |  |  |  |  | ↑\*\*\*\* | 4.8 | **↑\*\*\*\*** | 3.4 | **↑\*\*\*\*** | 5.5 | | **↑\*\*\*\*** | | 7.9 | |  | | 1.1 | |
|  | Males control |  |  |  |  | ↓\*↔0 | -0.5 |  | 0.3 |  | 0.7 | | ↔0 | | 0.1 | |  | | 1.5 | |
|  | HIIT – control |  |  |  |  | ↑\*\*\* | 5.3 | **↑\*\*\*** | 3.1 | ↑\*\*\* | 4.8 | | **↑\*\*\*\*** | | 7.7 | |  | | -0.3 | |
|  | Females HIIT |  |  |  |  |  |  |  |  | ↑\*\*\* | 12.3 | | **↑\*\*\*\*** | | 7.1 | |  | |  | |
|  | Females control |  |  |  |  |  |  |  |  |  | -0.2 | |  | | -0.3 | |  | |  | |
|  | HIIT – control |  |  |  |  |  |  |  |  | ↑\*\*\* | 12.6 | | ↑\*\*\*\* | | 7.4 | |  | |  | |
| **Other athletes** | |  | |  | |  | |  | |  | | |  | | | |  | |  | |
|  | Males HIIT | ↑\*\*\* | 4.2 | ↑\*\*\* | 3.2 |  |  | ↔0 | 0.0 | ↑\*\* | 6.1 | | ↑\*\*\*\* | | 11.1 | |  | | 1.1 | |
|  | Males control | ↓\*\* | -2.3 | ↓\*↔0 | -0.7 |  |  | ↓\*↔0 | -1.3 |  | 1.0 | | ↑\*\* | | 2.3 | |  | | 1.5 | |
|  | HIIT – control | ↑\*\*\* | 6.7 | ↑\*\* | 3.9 |  |  |  | 1.3 |  | 5.1 | | ↑\*\*\*\* | | 8.6 | |  | | -0.3 | |
|  | Females HIIT |  |  |  | -1.1 |  |  |  |  | ↑\*\* | 7.6 | | ↑\*\*\*\* | | 12.5 | |  | |  | |
|  | Females control |  |  | ↓\* | -2.2 |  |  |  |  |  | 1.4 | |  | | 0.9 | |  | |  | |
|  | HIIT – control |  |  |  | 1.1 |  |  |  |  |  | 6.2 | | ↑\*\*\*\* | | 11.5 | |  | |  | |
|  | Males YoYo HIIT |  |  |  |  |  |  | ↑\*\* | 1.7 |  |  | |  | |  | |  | |  | |
|  | Males YoYo control |  |  |  |  |  |  |  | 0.5 |  |  | |  | |  | |  | |  | |
|  | HIIT – control |  |  |  |  |  |  |  | 1.2 |  |  | |  | |  | |  | |  | |
|  | | | | | | | | | | | | | | | | |  | |  | |
|  | | | | | | | | | | | | | | | | |  | |  | |
| ***Moderator effects*** | |  | |  | |  | |  | |  | | |  | | | |  | |  | |
| **Male – female athletes for HIIT – control** | | | | | | | | | | | | | | | | |  | |  | |
|  | Endurance athletes |  |  |  |  |  |  |  |  |  | -6.9 | |  | | -0.3 | |  | |  | |
|  | Other athletes |  |  |  | 2.8 |  |  |  |  |  | -1.0 | |  | | -2.6 | |  | |  | |
| **Endurance – other athletes for HIIT – control** | | | | | | | | | | | | | | | | |  | |  | |
|  | Males |  |  |  |  |  |  |  | 1.7 |  | 0.3 | |  | | -0.8 | |  | |  | |
|  | Females |  |  |  |  |  |  |  |  |  | 6.0 | |  | | -3.7 | |  | |  | |
| **Yoyo – Incr. for HIIT – control** | | | | | | | | | | | | | | | | |  | |  | |
|  | Males |  |  |  |  |  |  |  | -0.2 |  |  | |  | |  | |  | |  | |
| **Type of HIITh** | |  |  |  |  |  |  |  |  |  |  | |  | |  | |  | |  | |
|  | Type 4.0 vs 1.0 HIIT |  | -0.4 |  | -1.0 |  | 0.4 | ↔00 | -0.3 |  | -2.7 | | **↓\*\*\*** | | -2.6 | |  | |  | |
| **Intervention duration** | | +5g wk | | +4 wk | | +6 wk | | +8 wk | | +7 wk | | | +5 wk | | | |  | |  | |
|  | HIIT | ↔0↑\* | 0.7 | ↑\*\* | 2.7 |  | 0.5 | ↔0↑\* | 1.0 | ↓\*\* | -1.3 | | ↔0**↑**\* | | 1.2 | |  | |  | |
|  | Control |  | -0.9 |  | 2.4 |  | 5.2 |  | 2.1 |  | 2.1 | | ↑\* | | 1.7 | |  | |  | |
|  | HIIT – control | ↔0↑\* | 1.6 |  | 0.3 |  | 4.5 |  | -1.1 | ↓\*\* | -3.3 | |  | | -0.6 | |  | |  | |
| **Training phase** | |  | |  | |  |  |  |  |  |  | |  | | | |  | |  | |
|  | On-season HIIT | ↑**\*\*\*** | 2.6 |  | 1.2 |  |  |  |  |  |  | | ↑**\*\*\*** | | 3.6 | |  | |  | |
|  | On-season cont | ↑\*↔0 | 1.6 |  | -1.1 |  |  |  |  |  |  | |  | | -0.6 | |  | |  | |
|  | On-season HIIT – control |  | 1.0 |  | 2.2 |  |  |  |  |  |  | | ↑**\*\*\*** | | 4.3 | |  | |  | |
| **Training implementation** | |  |  |  |  |  |  |  |  |  |  | |  | |  | |  | |  | |
|  | HIIT as extra training | ↔0↑\* | 1.3 |  | 0.4 |  | 1.8 | ↔0↑\* | 1.2 |  | -1.6 | | ↔0↑\* | | 1.1 | |  | |  | |
|  | Extra control training |  |  |  |  |  |  |  |  |  | -0.8 | |  | | -1.2 | |  | |  | |
|  | HIIT – control |  |  |  |  |  |  |  |  |  | -0.8 | | **↑\*\*** | | 2.3 | |  | |  | |
| ***Pre-test moderators*** | |  | |  |  |  | |  | |  |  |  | |  | |  | |  | |
| **Test duration:** | | 10 vs 2.5 s | |  |  | +40 min | | +8 min | |  |  |  | |  | |  | |  | |
|  | HIIT | ↑\*\*\* | 2.9 |  |  | **↑\*\*** | 2.7 | ↔0↑\* | 0.4 |  |  | |  | |  | |  | |  | |
|  | Control |  | -2.5 |  |  | ↓\*\* | -2.1 |  | -0.8 |  |  | |  | |  | |  | |  | |
|  | HIIT – control | ↑\*\*\* | 5.5 |  |  | **↑\*\*\*** | 4.9 |  | 1.2 |  |  | |  | |  | |  | |  | |
| **Other measures:** | |  |  | Decr.g +3% | |  |  |  |  | Threshold +10% | | | V̇O2max +20% | | | | Intensity +20% | | | |
|  | HIIT |  |  | ↑\*\*\* | 5.3 |  |  |  |  | ↓\*↔0 | -0.8 | | **↓\*\*** | | -1.8 | |  | | 0.3 | |
|  | Control |  |  |  | 1.2 |  |  |  |  |  | -0.7 | |  | | -0.4 | |  | | 0.0 | |
|  | HIIT – control |  |  |  | 4.0 |  |  |  |  |  | 0.0 | | ↓\* ↔0 | | -1.4 | |  | | 0.2 | |
|  |  |  |  |  |  |  |  |  |  |  |  | |  | |  | |  | |  | |
|  | |  |  |  |  |  |  |  |  |  |  | |  | |  | |  | |  | |
| ***Heterogeneity SD*** | |  |  |  |  |  |  |  |  |  |  | |  | |  | |  | |  | |
|  | HIIT | ↑\*\* | 1.2 |  | 1.2 | ↑\*\* | 1.3 |  | 1.3 |  | 2.3 | |  | | 1.1 | |  | | 2.2 | |
|  | Control |  | 0.6 |  | 2.3 |  | 0.7 |  | 1.8 |  | 1.0 | |  | | 0.4 | |  | |
|  |  |  |  |  |  |  |  |  |  |  |  | |  | |  | |  | |  | |
|  | |  |  |  |  |  |  |  |  |  |  | |  | |  | |  | |  | |
| ***Error of measurement SDi*** | |  |  |  |  |  |  |  |  |  |  | |  | |  | |  | |  | |
|  | HIIT |  | 2.2 |  | 1.4 |  | 3.2 |  | 2.9 |  | 3.5 | |  | | 3.1 | |  | | 6.0 | |
|  | Control |  | 1.9 |  | 1.3 |  | 1.9 |  | 1.9 |  | 4.4 | |  | | 3.4 | |  | | 3.6 | |
| ***Individual responses SDj*** | |  | 2.2 |  | 0.7 |  | 3.6 |  | 3.1 |  | -3.8 | |  | | -2.0 | |  | | 6.8 | |
| V̇O2max, maximum oxygen uptake; Decr., repeated-sprint ability decrement.  Sign and probability are shown for effects with adequate precision at the 90% or 99% level. ↑↓ Indicate substantial positive and negative effects, respectively; ↔ indicates trivial effects. Probabilities of substantial effects: \*, possibly; \*\*, likely; \*\*\*, very likely; \*\*\*\*, most likely. Probabilities of trivial effects: 0, possibly; 00, likely; 000, very likely; 0000, most likely.  Predicted effects (a-g) and other explanations (h-j):  a 10-s test; HIIT as replacement training, on-season; six weeks; aerobic rank 3  b decrement 5%; HIIT as replacement training, on-season; five weeks; aerobic rank 4  c 45-m test, HIIT as replacement training, on-season; five weeks; aerobic rank 2  d 8-min incremental test; HIIT as replacement training, on-season; five weeks; aerobic rank 3  e pre-test intensity of 80% of V̇O2max; HIIT as replacement training, off-season; six weeks; aerobic rank 1  f pre-test V̇O2max, 63 ml∙kg-1∙min-1 for female and male endurance athletes, 41 and 51 ml∙kg-1∙min-1 for female and male other athletes; HIIT as replacement training, on-season; five weeks; aerobic rank 1  g exercise-test intensity, 70% of V̇O2max  h Range of 1.0 (aerobic HIIT with traditional long intervals) to 6.0 (SIT: anaerobic sprint intervals), as presented in Figure 1 in Wiesinger et al. [36]  i Averaged across studies, where they could be estimated.  j Estimated as √(2eH2 – 2eC2), where eH and eC are the errors of measurement in HIIT and control groups, respectively. | | | | | | | | | | | | | | | | | | | | |

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