****Efficacy and Optimal Dosage of Various Exercises for Migraine: A Multilevel Network and Dose-Response Meta-analysis****

**Supplementary Files**

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**Supplementary 1: Search Strategy**

## 2.1 MEDLINE

**Table S1 Search Strategy**

|  |  |
| --- | --- |
| **Search** | **Query** |
| #1 | "Migraine"[Mesh] |
| #2 | ((((((((((((((((((((Disorder, Migraine) OR (Disorders, Migraine)) OR (Migraine Disorder)) OR (Headache, Migraine)) OR (Headaches, Migraine)) OR (Migraine Headaches)) OR (Migraine Headache)) OR (Acute Confusional Migraine)) OR (Migraine, Acute Confusional)) OR (Status Migrainosus)) OR (Abdominal Migraine)) OR (Migraine, Abdominal)) OR (Cervical Migraine Syndrome)) OR (Migraine Syndrome, Cervical)) OR (Hemicrania Migraine)) OR (Migraine, Hemicrania)) OR (Migraine Variant)) OR (Variant, Migraine)) OR (Sick Headache)) OR (Headache, Sick)) OR (Headache) |
| #3 | ("Migraine"[Mesh]) OR ((((((((((((((((((((Disorder, Migraine) OR (Disorders, Migraine)) OR (Migraine Disorder)) OR (Headache, Migraine)) OR (Headaches, Migraine)) OR (Migraine Headaches)) OR (Migraine Headache)) OR (Acute Confusional Migraine)) OR (Migraine, Acute Confusional)) OR (Status Migrainosus)) OR (Abdominal Migraine)) OR (Migraine, Abdominal)) OR (Cervical Migraine Syndrome)) OR (Migraine Syndrome, Cervical)) OR (Hemicrania Migraine)) OR (Migraine, Hemicrania)) OR (Migraine Variant)) OR (Variant, Migraine)) OR (Sick Headache)) OR (Headache, Sick)) OR (Headache) |
| #4 | "Exercise"[Mesh] |
| #5 | (((((((((((((((((((((((((((((((Exercises) OR (Exercise, Physical)) OR (Exercises, Physical)) OR (Physical Exercise)) OR (Physical Exercises)) OR (Exercise, Aerobic)) OR (Aerobic Exercise)) OR (Aerobic Exercises)) OR (Exercises, Aerobic)) OR (Exercise, Isometric)) OR (Exercises, Isometric)) OR (Isometric Exercises)) OR (Isometric Exercise)) OR (Acute Exercise)) OR (Acute Exercises)) OR (Exercise, Acute)) OR (Exercises, Acute)) OR (Exercise Training)) OR (Exercise Trainings)) OR (Training, Exercise)) OR (Trainings, Exercise)) OR (Physical Activity)) OR (Activities, Physical)) OR (Activity, Physical)) OR (Physical Activities)) OR (Yoga)) OR (Pilates)) OR (Aquatic exercise)) OR (Qi gong)) OR (Wu qin xi)) OR (Stretch)) OR (Strength) Sort by: Most Recent |
| #6 | ("Exercise"[Mesh]) OR ((((((((((((((((((((((((((((((((Exercises) OR (Exercise, Physical)) OR (Exercises, Physical)) OR (Physical Exercise)) OR (Physical Exercises)) OR (Exercise, Aerobic)) OR (Aerobic Exercise)) OR (Aerobic Exercises)) OR (Exercises, Aerobic)) OR (Exercise, Isometric)) OR (Exercises, Isometric)) OR (Isometric Exercises)) OR (Isometric Exercise)) OR (Acute Exercise)) OR (Acute Exercises)) OR (Exercise, Acute)) OR (Exercises, Acute)) OR (Exercise Training)) OR (Exercise Trainings)) OR (Training, Exercise)) OR (Trainings, Exercise)) OR (Physical Activity)) OR (Activities, Physical)) OR (Activity, Physical)) OR (Physical Activities)) OR (Yoga)) OR (Pilates)) OR (Aquatic exercise)) OR (Qi gong)) OR (Wu qin xi)) OR (Stretch)) OR (Strength)) |
| #7 | ((Randomized controlled trial[Title/Abstract]) OR (Randomized[Title/Abstract])) OR (Placebo[Title/Abstract]) |
| #9 | #3 AND #6 AND #7 |

**Supplementary 2: Characteristics of Included Studies**

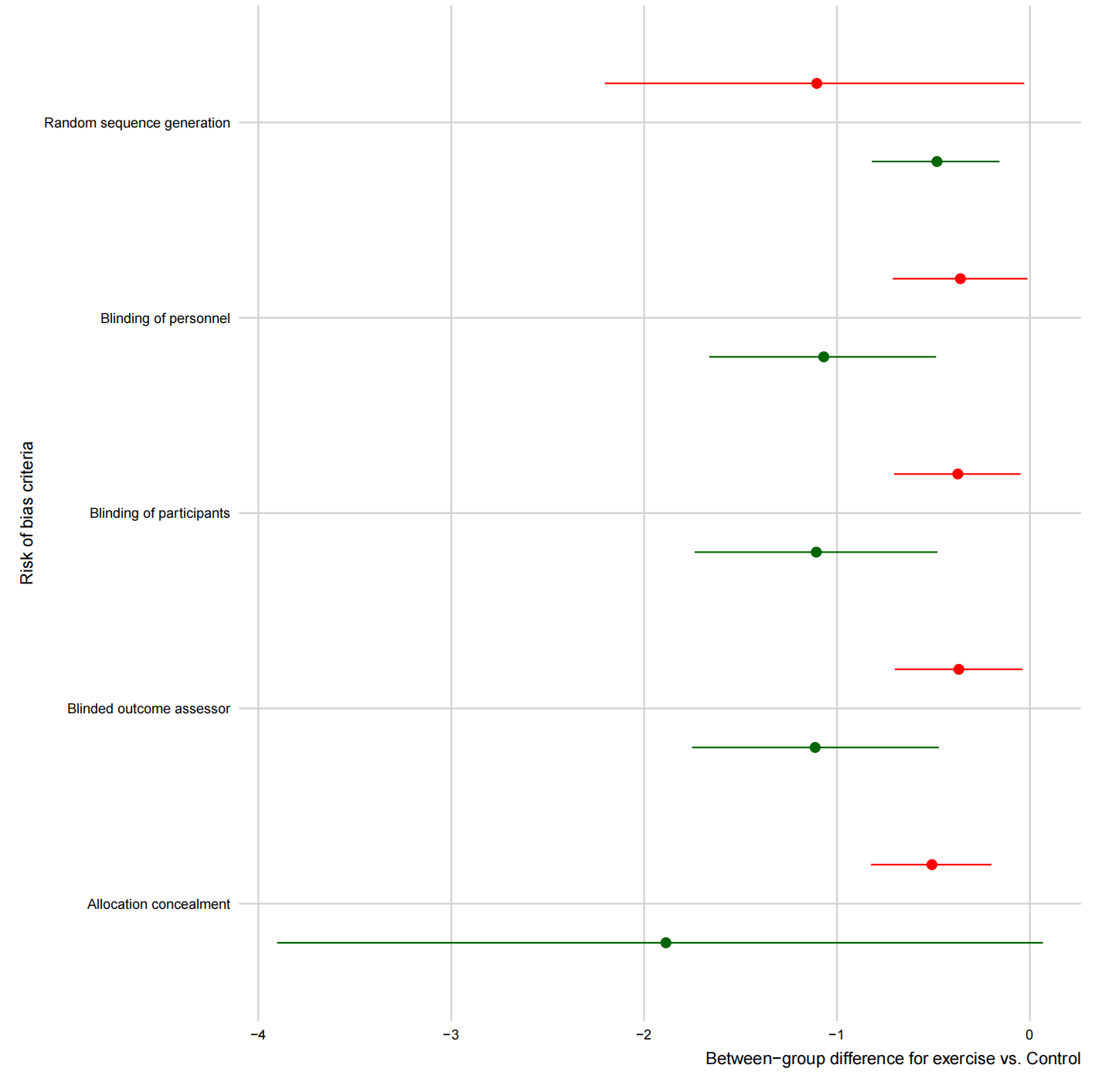
**Table S2 Characteristics of Included Studies**

| Country | Funded | n | % Female | Mean Age (SD/Range) | Session\_duration(min) | Supervise | Treatment | Duration (weeks) | Intensity prescribed (METs) | Exercise dose (METs/week) | Timepoints available | Outcomes measured |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Alipouri2023(1) | | | | | | | | | | | | |
| Iran | N | 12 | 1.00 | 25.33 (2.87) | 30 | Y | Aerobic | 8 | 3 | 270 | Post | VAS |
| Iran | N | 12 | 1.00 | 27.25 (4.63) | 0 | NA | Control | 0 | 0 | 0 | Post | VAS |
| Aslani2022(2) | | | | | | | | | | | | |
| Iran | Y | 12 | 1.00 | 30.25 (6.1) | 50 | Y | Resistance | 8 | 3 | 450 | Post | VAS |
| Iran | Y | 8 | 1.00 | 30.1 (7) | 0 | NA | Control | 0 | 0 | 0 | Post | VAS |
| Bond2018(3) | | | | | | | | | | | | |
| USA | Y | 54 | 1.00 | 38.5 (7.4) | 40 | Y | Aerobic | 16 | 4 | 480 | Post | HIT-6, NRS |
| USA | Y | 56 | 1.00 | 40 (8.4) | 0 | NA | Control | 0 | 0 | 0 | Post | HIT-6, NRS |
| Boroujeni2014(4) | | | | | | | | | | | | |
| Iran | Y | 21 | 1.00 | 35.4 (7.9) | 75 | Y | Yoga | 12 | 2 | 518 | Post | VAS |
| Iran | Y | 21 | 1.00 | 34.9 (8.37) | 0 | NA | Control | 0 | 0 | 0 | Post | VAS |
| Butt2022(5) | | | | | | | | | | | | |
| Pakistan | N | 14 | 0.85 | 33.2 (11.69) | 50 | Y | Aerobic | 12 | 4 | 400 | Post, 6 weeks | HIT-6, NRS |
| Pakistan | N | 14 | 0.85 | 26.21 (6.89) | 0 | NA | Control | 0 | 0 | 0 | Post, 6 weeks | HIT-6, NRS |
| Darabanea2011(6) | | | | | | | | | | | | |
| USA | Y | 8 | NA | NA (NA) | 30 | Y | Aerobic | 10 | 4 | 360 | Post | NRS |
| USA | Y | 8 | NA | NA (NA) | 0 | NA | Control | 0 | 0 | 0 | Post | NRS |
| Eslami2021(7) | | | | | | | | | | | | |
| Iran | Y | 15 | 1.00 | 38.41 (6.2) | 40 | Y | Aerobic | 8 | 4 | 360 | Post | VAS |
| Iran | Y | 15 | 1.00 | 25.16 (6.08) | 40 | Y | HIIT | 8 | 7 | 840 | Post | VAS |
| Iran | Y | 15 | 1.00 | 32.44 (5.74) | 0 | NA | Control | 0 | 0 | 0 | Post | VAS |
| John2007(8) | | | | | | | | | | | | |
| India | Y | 36 | 0.45 | 34.38 (8.74) | 60 | Y | Yoga | 12 | 2 | 690 | Post | T-PRI, VAS |
| India | Y | 36 | 0.18 | NA (NA) | 0 | NA | Control | 0 | 0 | 0 | Post | T-PRI, VAS |
| Johnson2025(9) | | | | | | | | | | | | |
| USA | Y | 11 | 0.98 | 28.6 (4) | 30 | Y | Aerobic | 4 | 3 | 270 | Post | Migraine intensity scale |
| USA | Y | 9 | 0.96 | 32.9 (4) | 0 | NA | Control | 0 | 0 | 0 | Post | Migraine intensity scale |
| Kaushal2023(10) | | | | | | | | | | | | |
| India | N | 40 | 0.87 | 37.1 (10.2) | 30 | Y | Yoga | 3 | 2 | 345 | Post | HIT-6, VAS |
| India | N | 40 | 0.95 | 35.98 (8.69) | 0 | NA | Control | 0 | 0 | 0 | Post | HIT-6, VAS |
| Kisan2014(11) | | | | | | | | | | | | |
| India | Y | 47 | 0.70 | 31.72 (10.77) | 30 | Y | Yoga | 6 | 2 | 138 | Post | VAS |
| India | Y | 37 | 0.63 | 31.27 (8.63) | 0 | NA | Control | 0 | 0 | 0 | Post | VAS |
| Krøll2017(12) | | | | | | | | | | | | |
| Denmark | Y | 36 | 0.88 | 42 (10.9) | 45 | Y | Aerobic | 4 | 4 | 540 | Post, 12 weeks | NRS |
| Denmark | Y | 34 | 0.88 | 36 (10.1) | 0 | NA | Control | 0 | 0 | 0 | Post, 12 weeks | NRS |
| Kumar2020(13) | | | | | | | | | | | | |
| India | Y | 80 | 0.72 | 30.5 (8.01) | 30 | Y | Yoga | 8 | 2 | 345 | Post | HIT-6, NRS |
| India | N | 80 | 0.72 | 30.5 (8.01) | 30 | Y | Yoga | 8 | 2 | 207 | Post | HIT-6, NRS |
| India | Y | 80 | 0.66 | 31.9 (8.17) | 0 | NA | Control | 0 | 0 | 0 | Post | HIT-6, NRS |
| India | N | 80 | 0.66 | 31.9 (8.17) | 0 | NA | Control | 0 | 0 | 0 | Post | HIT-6, NRS |
| Kumari2022(14) | | | | | | | | | | | | |
| India | N | 23 | 1.00 | 33.17 (5) | 30 | Y | Yoga | 3 | 2 | 345 | Post | HIT-6, VAS |
| India | N | 20 | 1.00 | 33.2 (5) | 0 | NA | Control | 0 | 0 | 0 | Post | HIT-6, VAS |
| Lemstra2002(15) | | | | | | | | | | | | |
| Canada | Y | 44 | 0.72 | 35.59 (10.15) | 30 | Y | Aerobic | 6 | 4 | 480 | Post | VAS |
| Canada | Y | 44 | 0.72 | 35.59 (10.15) | 30 | Y | Aerobic | 6 | 4 | 360 | 12 weeks | VAS |
| Canada | Y | 36 | 0.58 | 33.17 (13.21) | 0 | NA | Control | 0 | 0 | 0 | Post, 12 weeks | VAS |
| Matin2022(16) | | | | | | | | | | | | |
| Iran | N | 16 | 1.00 | 30 (4) | 40 | Y | HIIT | 8 | 5 | 840 | Post | MIDAS |
| Iran | N | 16 | 1.00 | 30.5 (4) | 0 | NA | Control | 0 | 0 | 0 | Post | MIDAS |
| Mehta2021(17) | | | | | | | | | | | | |
| India | Y | 21 | 0.85 | 39.15 (8.24) | 30 | Y | stretch | 12 | 2 | 420 | Post | HIT-6, VAS |
| India | Y | 20 | 0.65 | 34.3 (9.57) | 30 | Y | Yoga | 12 | 2 | 483 | Post | HIT-6, VAS |
| India | Y | 20 | 0.65 | 34.3 (9.57) | 30 | Y | Yoga | 8 | 2 | 483 | Post | HIT-6, VAS |
| India | Y | 20 | 0.65 | 34.3 (9.57) | 30 | Y | Yoga | 4 | 2 | 483 | Post | HIT-6, VAS |
| India | Y | 20 | 0.71 | 36.81 (10.85) | 0 | NA | Control | 0 | 0 | 420 | Post | HIT-6, VAS |
| India | Y | 20 | 0.71 | 36.81 (10.85) | 0 | NA | Control | 0 | 0 | 0 | Post | VAS |
| Narin2003(18) | | | | | | | | | | | | |
| Turkey | N | 20 | 1.00 | 35 (5) | 50 | Y | Aerobic | 8 | 4 | 1000 | Post | QLS |
| Turkey | N | 20 | 1.00 | 40.1 (4) | 50 | Y | Aerobic | 8 | 3 | 450 | Post | VAS |
| Turkey | N | 20 | 1.00 | 50.1 (5) | 0 | NA | Control | 0 | 0 | 0 | Post | QLS, VAS |
| Turkey | N | 20 | 1.00 | 40 (5.5) | 0 | NA | Control | 0 | 0 | 0 | Post | QLS, VAS |
| Niu2024(19) | | | | | | | | | | | | |
| Turkey | N | 50 | 0.51 | 68.35 (5.29) | 35 | Y | Aerobic+Resistance | 24 | 4 | 420 | Post | HIT-6, MIDAS |
| Turkey | N | 50 | 0.51 | 66.42 (4.51) | 0 | NA | Control | 0 | 0 | 0 | Post | HIT-6, MIDAS |
| Oliveira2019(20) | | | | | | | | | | | | |
| Brazil | N | 15 | 0.84 | 36.2 (10.9) | 40 | Y | Aerobic | 12 | 3 | 720 | Post | Migraine intensity scale |
| Brazil | N | 15 | 0.76 | 36.2 (10.9) | 0 | NA | Control | 0 | 0 | 0 | Post | Migraine intensity scale |
| Ozge2025(21) | | | | | | | | | | | | |
| Turkey | N | 20 | 1.00 | 31.1 (4.5) | 30 | Y | Aerobic | 8 | 3 | 180 | Post | VAS |
| Turkey | N | 20 | 1.00 | 30.7 (3.8) | 20 | Y | stretch | 8 | 2 | 80 | Post | VAS |
| Turkey | N | 20 | 1.00 | 30.4 (4.21) | 0 | NA | Control | 0 | 0 | 0 | Post | VAS |
| Ozlem2024(22) | | | | | | | | | | | | |
| Turkey | N | 20 | 1.00 | 35.8 (7.78) | 45 | Y | Yoga | 12 | 2 | 310 | Post | HIT-6, MIDAS, VAS |
| Turkey | N | 20 | 1.00 | 36.65 (9.62) | 0 | NA | Control | 0 | 0 | 0 | Post | HIT-6, MIDAS, VAS |
| Peres2018(23) | | | | | | | | | | | | |
| Brazil | Y | 25 | 0.80 | 41.8 (19.7) | 30 | Y | Aerobic | 24 | 4 | 360 | Post | NRS |
| Brazil | Y | 25 | 0.84 | 41.1 (16.4) | 0 | NA | Control | 0 | 0 | 0 | Post | NRS |
| Rahimi2022(24) | | | | | | | | | | | | |
| Iran | N | 24 | 1.00 | 31.65 (6.4) | 30 | Y | Aerobic | 12 | 3 | 360 | Post, 54 weeks | VAS |
| Iran | N | 24 | 1.00 | 31.61 (4.87) | 0 | NA | Control | 0 | 0 | 0 | Post, 54 weeks | VAS |
| Sun2021(25) | | | | | | | | | | | | |
| China | Y | 145 | 0.81 | 33.1 (5.9) | 60 | Y | Resistance | 12 | 3 | 360 | Post, 16 weeks | VAS |
| China | Y | 141 | 0.83 | 34.5 (6.3) | 0 | NA | Control | 0 | 0 | 0 | Post, 16 weeks | VAS |
| Varkey2011(26) | | | | | | | | | | | | |
| Sweden | Y | 30 | 0.93 | 47 (10.8) | 30 | Y | Aerobic | 12 | 4 | 360 | Post, 12 weeks | VAS |
| Sweden | Y | 30 | 0.93 | 47 (10.8) | 40 | Y | Aerobic | 12 | 4 | 360 | 24 weeks | VAS |
| Sweden | Y | 30 | 0.83 | 41.5 (11.4) | 0 | NA | Control | 0 | 0 | 0 | Post, 12 weeks, 24 weeks | VAS |
| Xie2022(27) | | | | | | | | | | | | |
| China | Y | 42 | 1.00 | 50.9 (10.2) | 20 | Y | Tai Chi | 12 | 3 | 132 | Post, 24 weeks | VAS |
| China | Y | 40 | 1.00 | 47.1 (11.8) | 0 | NA | Control | 0 | 0 | 0 | Post, 24 weeks | VAS |

**Supplementary 3: Risk of Bias in Individual Studies**

**Table S3 Risk of Bias in Individual Studies**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Author, Year | Bias arising from the randomization process | Bias due to deviations from intended interventions | Bias due to missing outcome data | Bias in measurement of the outcome | Bias in selection of the reported result | Overall bias |
| Alipouri2023 | Low risk | Low risk | Low risk | Low risk | Low risk | Low |
| Aslani2022 | Some concerns | Some concerns | Some concerns | Some concerns | Some concerns | Unclear |
| Bond2018 | Low risk | Some concerns | Low risk | Low risk | Low risk | Unclear |
| Boroujeni2014 | Low risk | Some concerns | Some concerns | Some concerns | Low risk | Unclear |
| Butt2022 | Some concerns | High risk | Some concerns | Some concerns | Some concerns | High |
| Darabanea2011 | Low risk | Some concerns | Low risk | Low risk | Low risk | Unclear |
| Eslami2021 | Low risk | High risk | Some concerns | Some concerns | Some concerns | High |
| John2007 | Low risk | Some concerns | High risk | Some concerns | Some concerns | High |
| Johnson2025 | Low risk | Some concerns | Low risk | Some concerns | Low risk | Unclear |
| Kaushal2023 | Low risk | Some concerns | High risk | High risk | Some concerns | High |
| Kisan2014 | Low risk | Low risk | High risk | Some concerns | Some concerns | High |
| Krøll2017 | Low risk | Some concerns | Some concerns | Some concerns | Low risk | Unclear |
| Kumar2020 | Low risk | Low risk | Low risk | Low risk | Low risk | Low |
| Kumari2022 | Low risk | Some concerns | Low risk | Low risk | Low risk | Unclear |
| Lemstra2002 | Low risk | Low risk | Low risk | Low risk | Low risk | Low |
| Matin2022 | Low risk | Some concerns | Low risk | Low risk | Low risk | Unclear |
| Mehta2021 | Low risk | Low risk | Some concerns | Some concerns | Some concerns | Unclear |
| Narin2003 | Some concerns | Some concerns | Some concerns | High risk | Low risk | High |
| Niu2024 | Low risk | Some concerns | Low risk | Some concerns | Low risk | Unclear |
| Oliveira2019 | Low risk | Some concerns | High risk | High risk | High risk | High |
| Ozge2025 | Low risk | Some concerns | Low risk | Some concerns | Low risk | Unclear |
| Ozlem2024 | Low risk | Some concerns | Low risk | Some concerns | Low risk | Unclear |
| Peres2018 | Low risk | Some concerns | Some concerns | Some concerns | Some concerns | Unclear |
| Rahimi2022 | Low risk | Some concerns | Low risk | Some concerns | Low risk | Unclear |
| Sun2021 | Low risk | Some concerns | Low risk | Low risk | Low risk | Unclear |
| Varkey2011 | Low risk | Some concerns | Low risk | Some concerns | Low risk | Unclear |
| Xie2022 | Low risk | Low risk | Low risk | Low risk | Low risk | Low |



**Figure S1 Risk of Bias in Individual Studies**

**Supplementary 4: The details of CINeMA**

**Table S4. Summary table for credibility assessment using confidence in network meta-analysis (CINeMA)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Control group versus** | **Direct**  **comparisons (k)** | **Within**  **study bias** | **Reporting**  **bias** | **Indirectness** | **Imprecision** | **Heterogeneity** | **Incoherence** | **Confidence**  **rating** |
| Aerobic exercise | 16 | ● | ● | ● | ● | ● | ● | Low |
| Yoga | 9 | ● | ● | ● | ● | ● | ● | Low |
| Tai Chi | 1 | ● | ● | ● | ● | ● | ● | Very low |
| Resistance exercise | 2 | ● | ● | ● | ● | ● | ● | Low |
| Aerobic+resistance exercise | 1 | ● | ● | ● | ● | ● | ● | Low |
| HIIT | 2 | ● | ● | ● | ● | ● | ● | Very low |
| stretch exercise | 2 | ● | ● | ● | ● | ● | ● | Low |

**Risk of bias**

● Major concerns or high ● Some concerns or unclear ● No concerns or low

**Supplementary 5: node-splitting analysis**

**Table S5 node-splitting analysis**

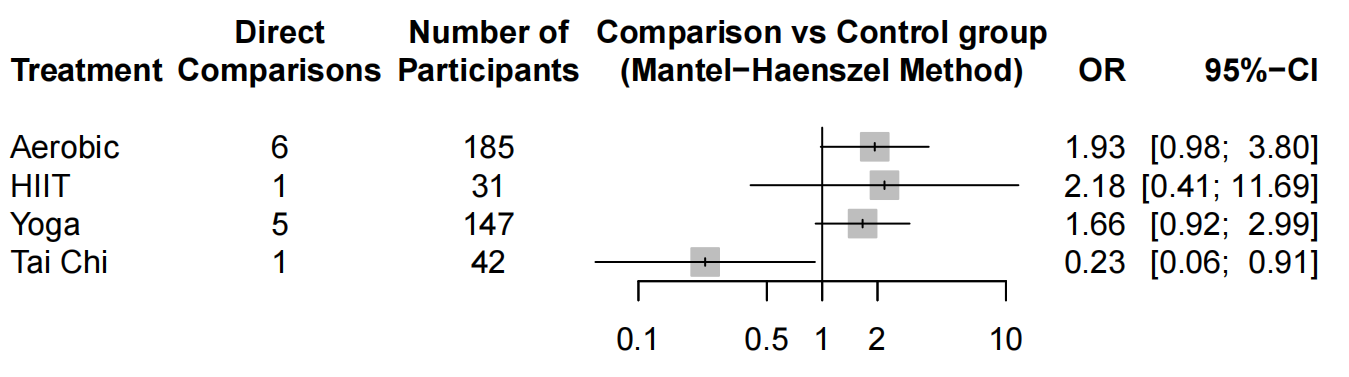
|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| comparison | k | prop | NMA | Direct | indirect | Diff | z | p |
| Aerobic : Control | 14 | 0.98 | –0.4017 | –0.3787 | –1.6750 | 1.2963 | 0.85 | 0.395 |
| Aerobic : HIIT | 1 | 0.53 | 0.2203 | –0.8965 | 1.464 | –2.3605 | –1.9 | 0.051 |
| Aerobic : stretch | 1 | 0.36 | –0.2928 | 0.221 | –0.5836 | 0.8046 | 0.79 | 0.430 |
| HIIT : Control | 2 | 0.86 | –0.6219 | –0.9625 | 1.5143 | –2.4769 | –1.48 | 0.139 |
| stretch : Control | 2 | 0.76 | –0.1089 | 0.2753 | –1.3411 | 1.6164 | 1.47 | 0.141 |
| Yoga : Control | 8 | 0.98 | –0.4905 | –0.4857 | –0.7597 | 0.274 | 0.14 | 0.885 |
| stretch : Yoga | 1 | 0.51 | 0.3817 | 0.1352 | 0.6395 | –0.5042 | –0.51 | 0.609 |

**Supplementary 6: Funnel plot**

漏斗图_00

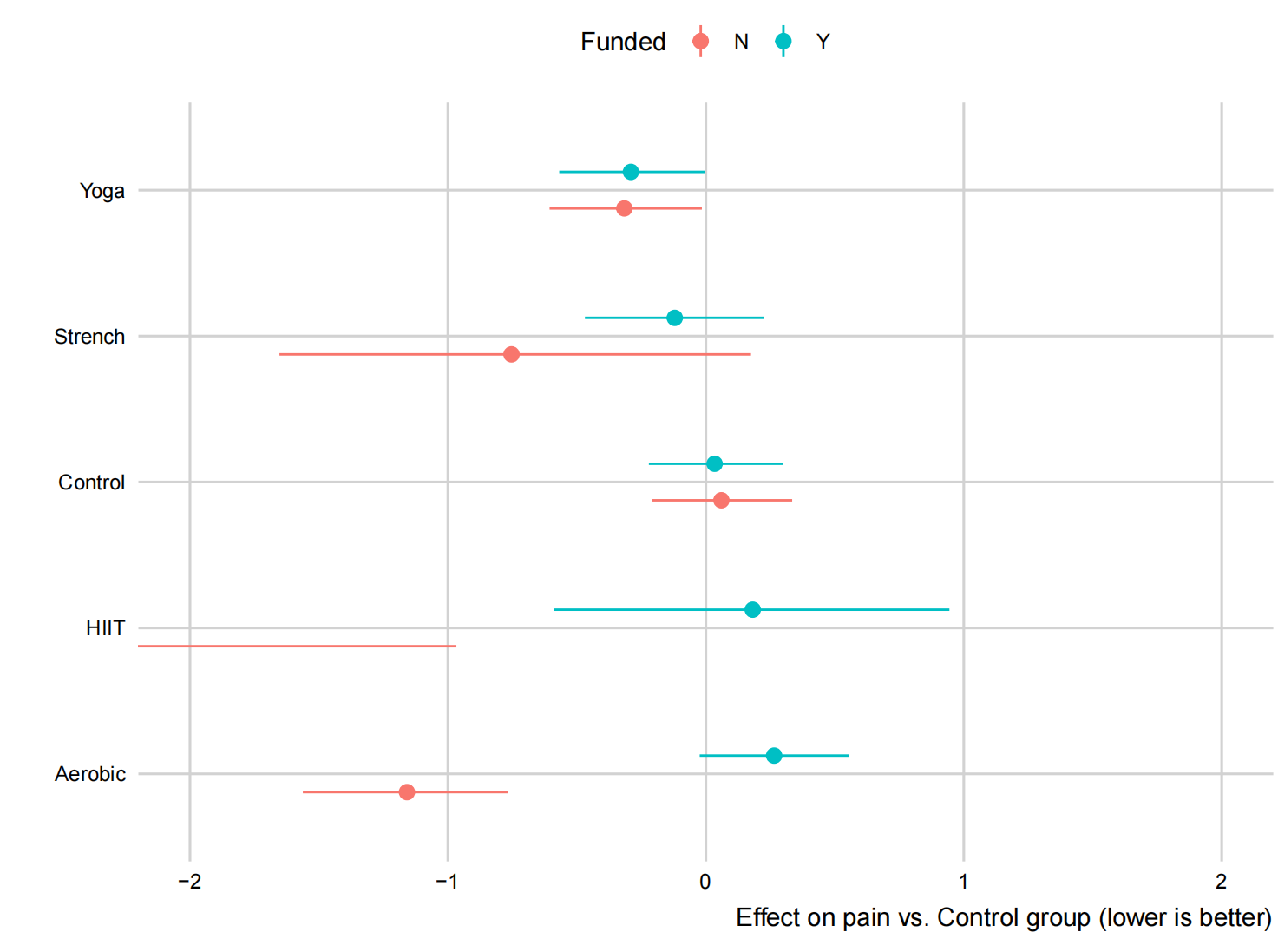
**Figure S2 Funnel plots**

**Supplementary 7: Acceptability**

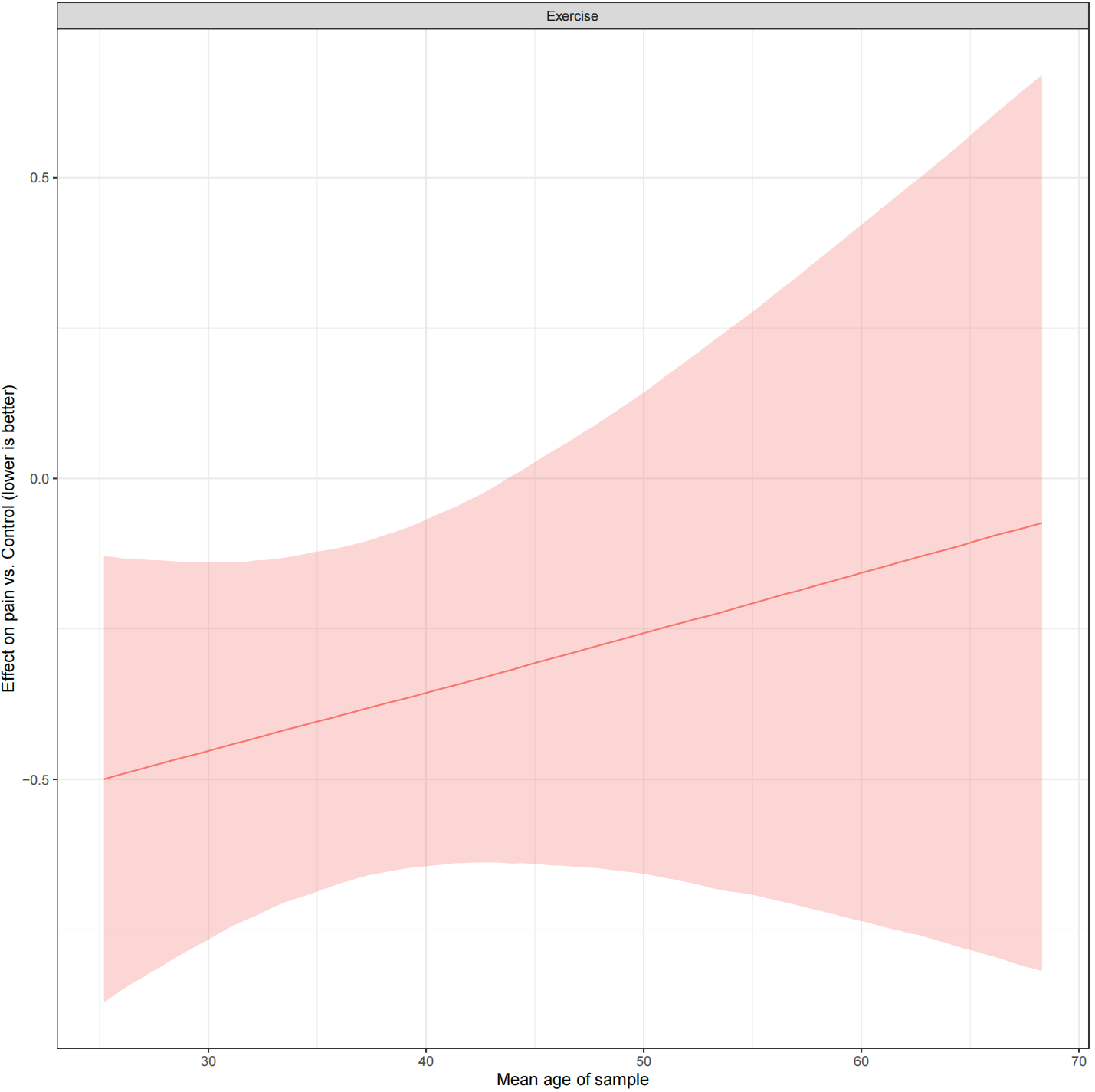


**Figure S3 Acceptability**

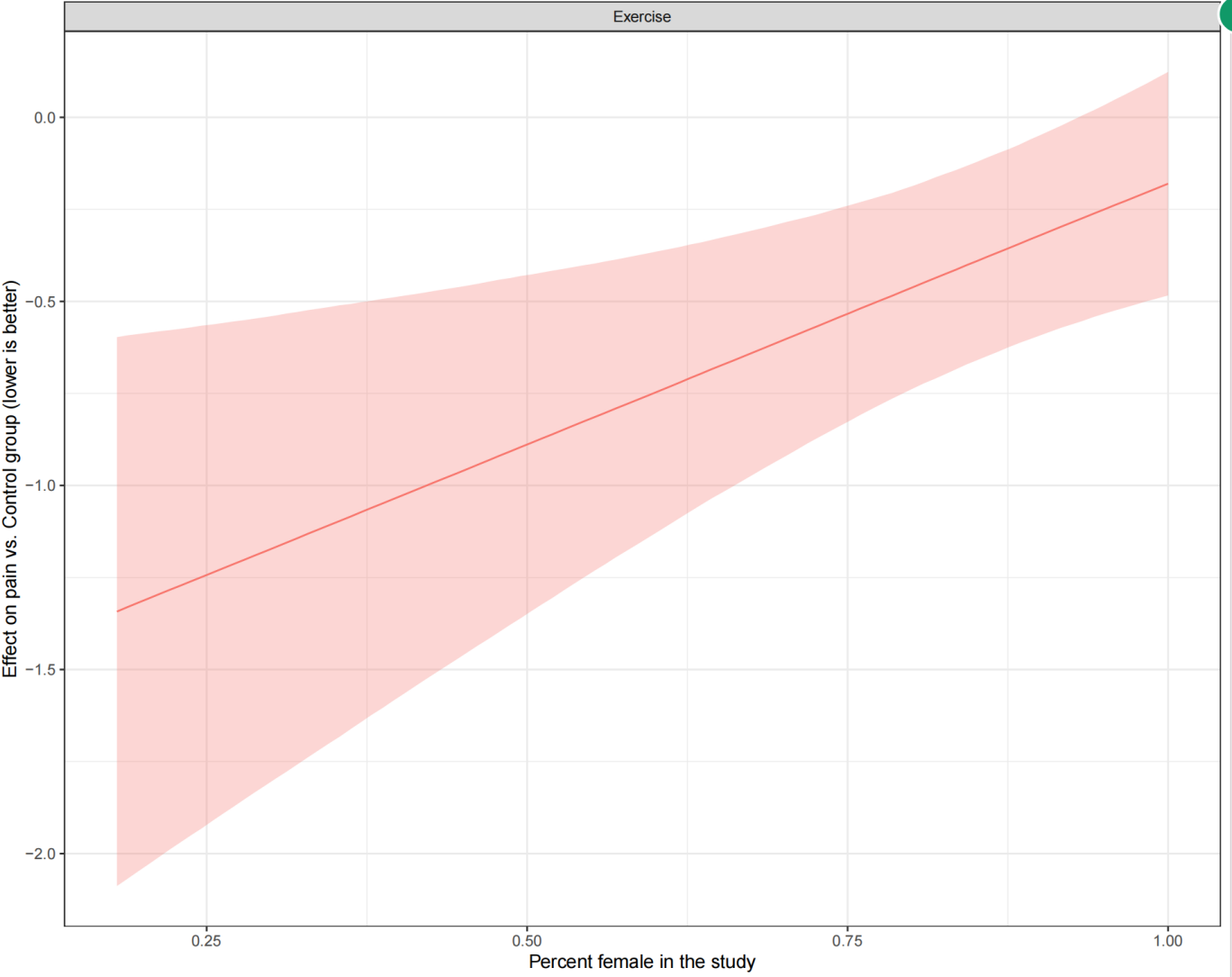
**Supplementary 8: Subgroup analysis**



**Figure S4(a) Moderation by funded**

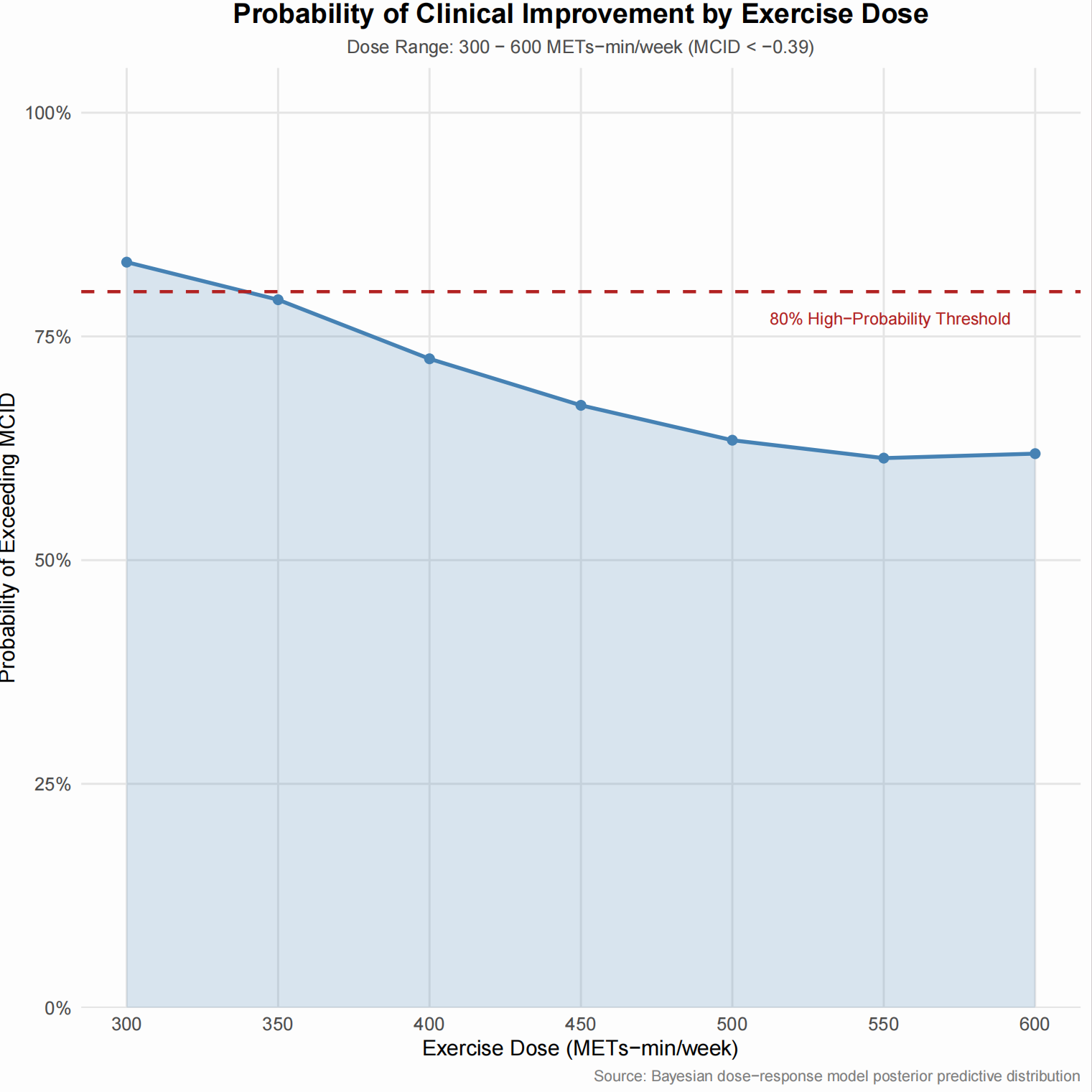


**Figure S4(b) Moderation by age**

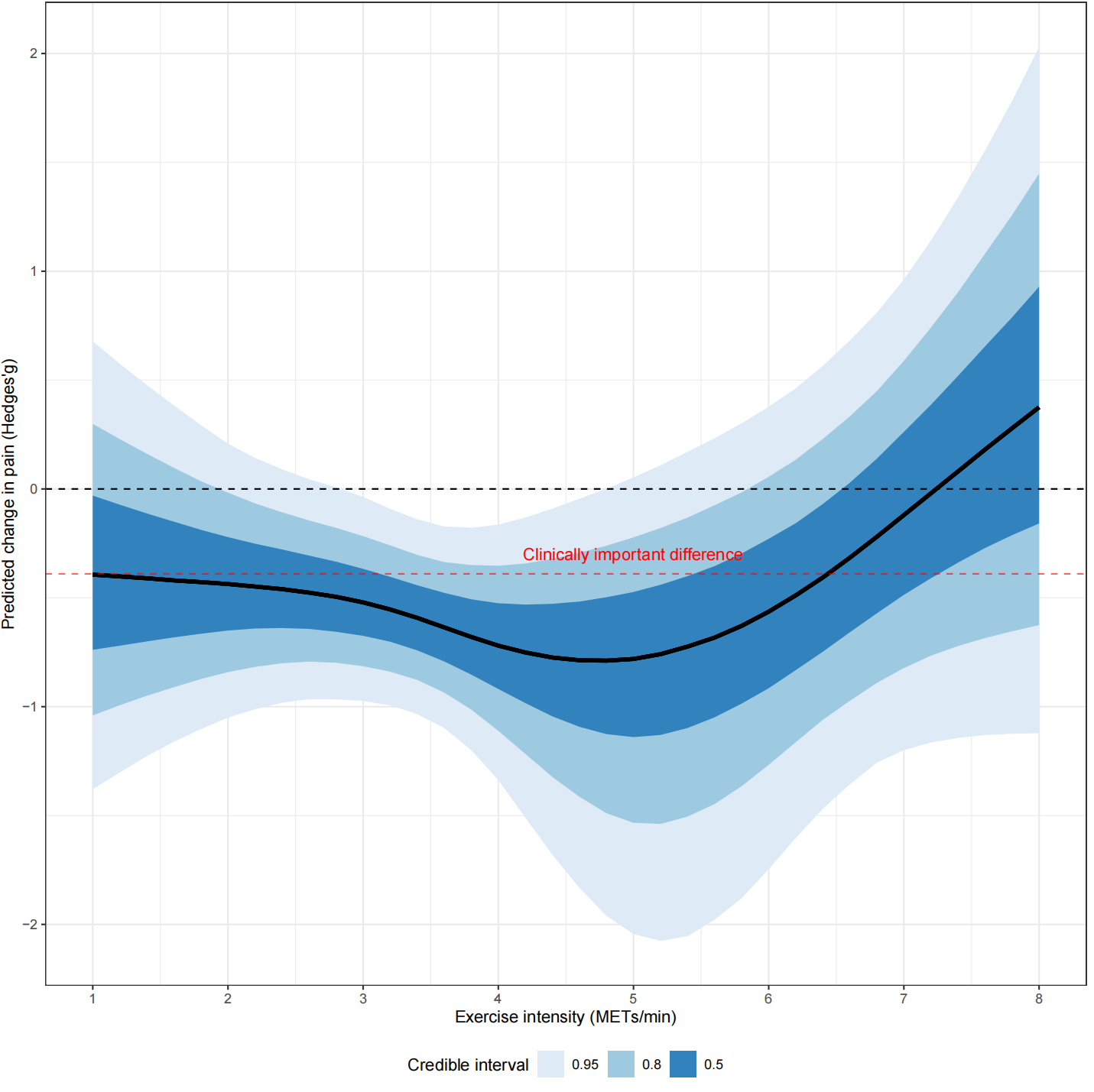


**Figure S4(c) Moderation by sex**

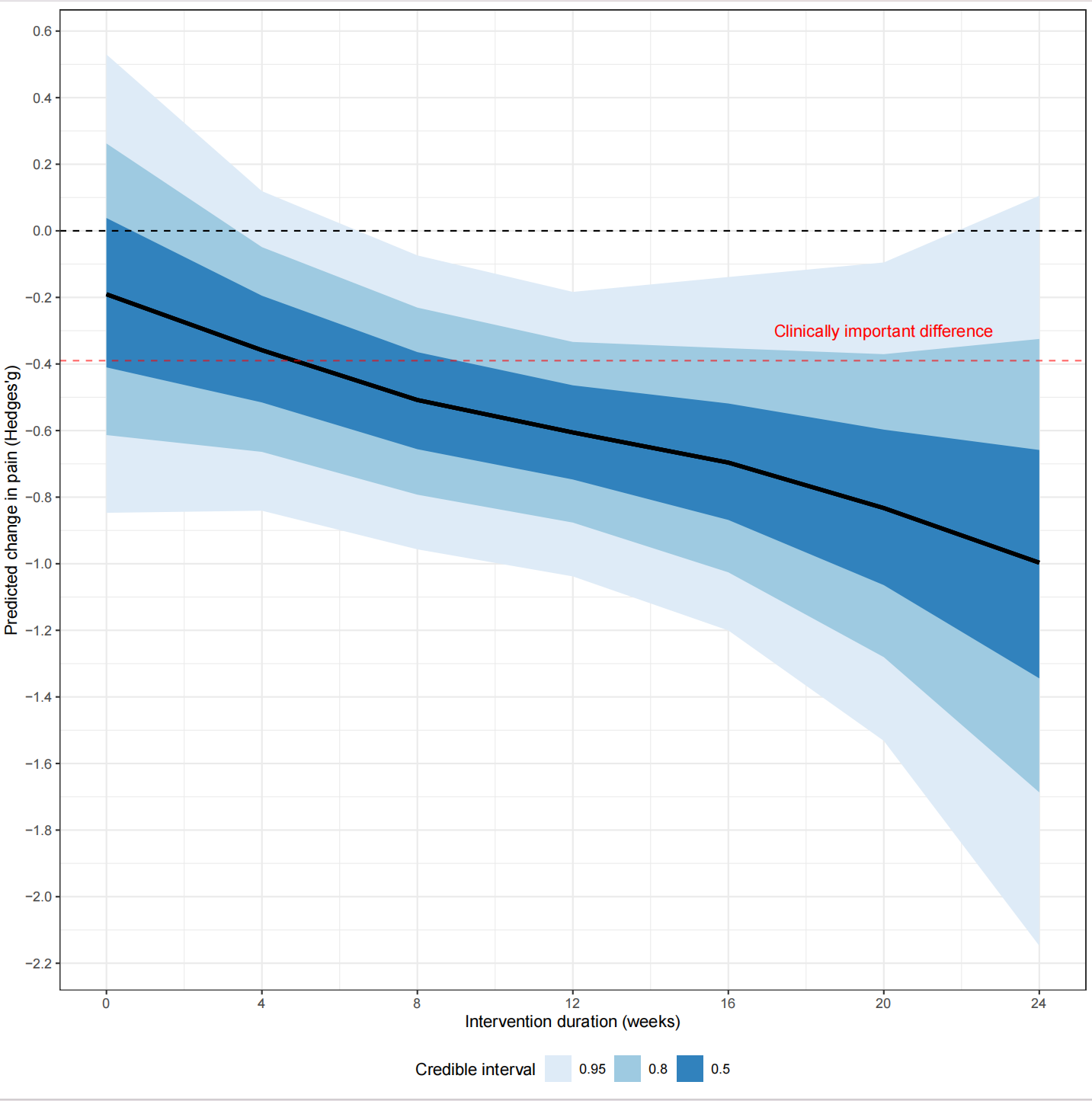
**Supplementary 9: Dose-response relationship**



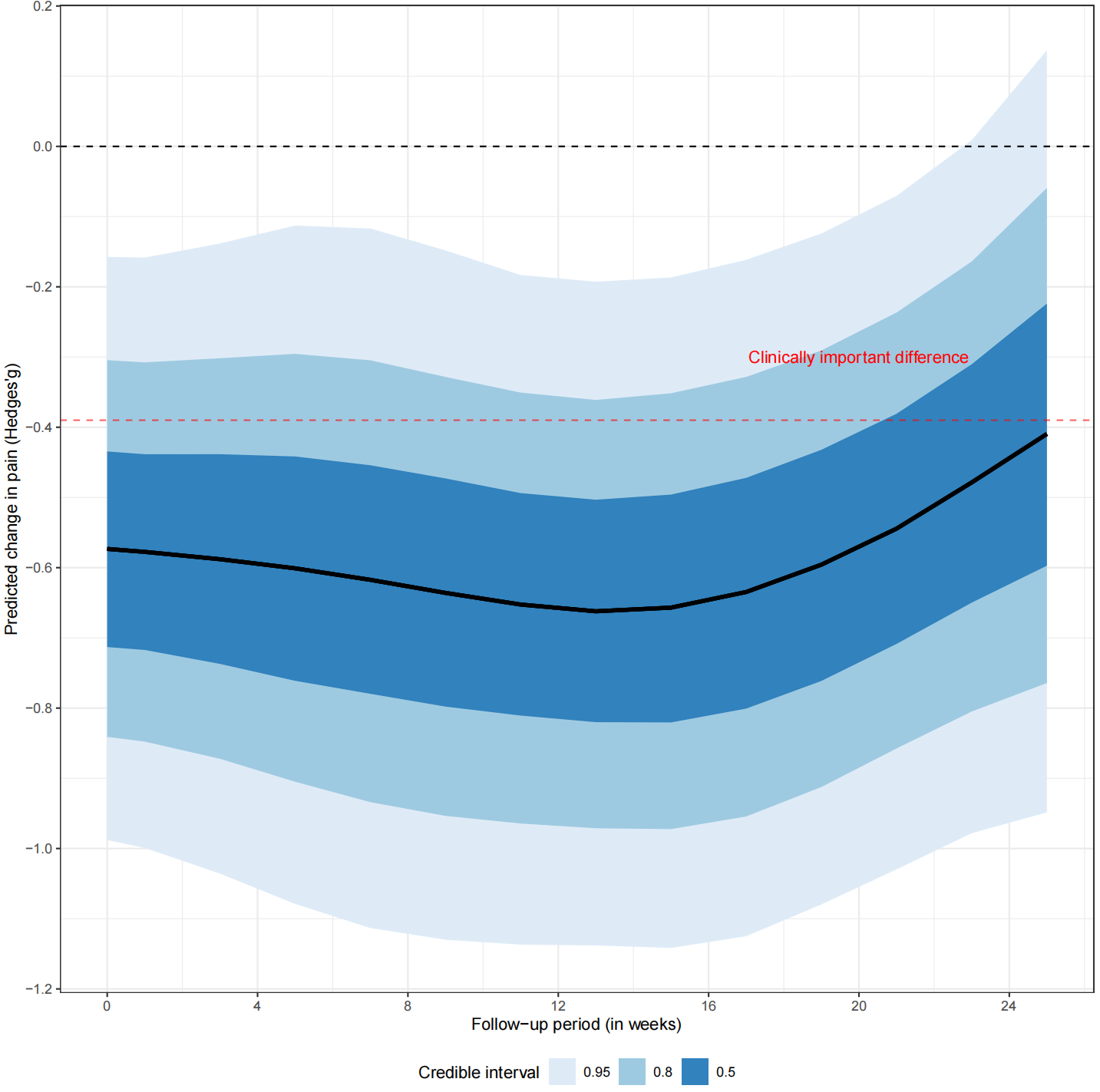
**Figure S5(a) Probability of Clinical Improvement by Exercise Dose**



**Figure 5(b) Dose-response relationship of exercise intensity (Minutes) to migraine**

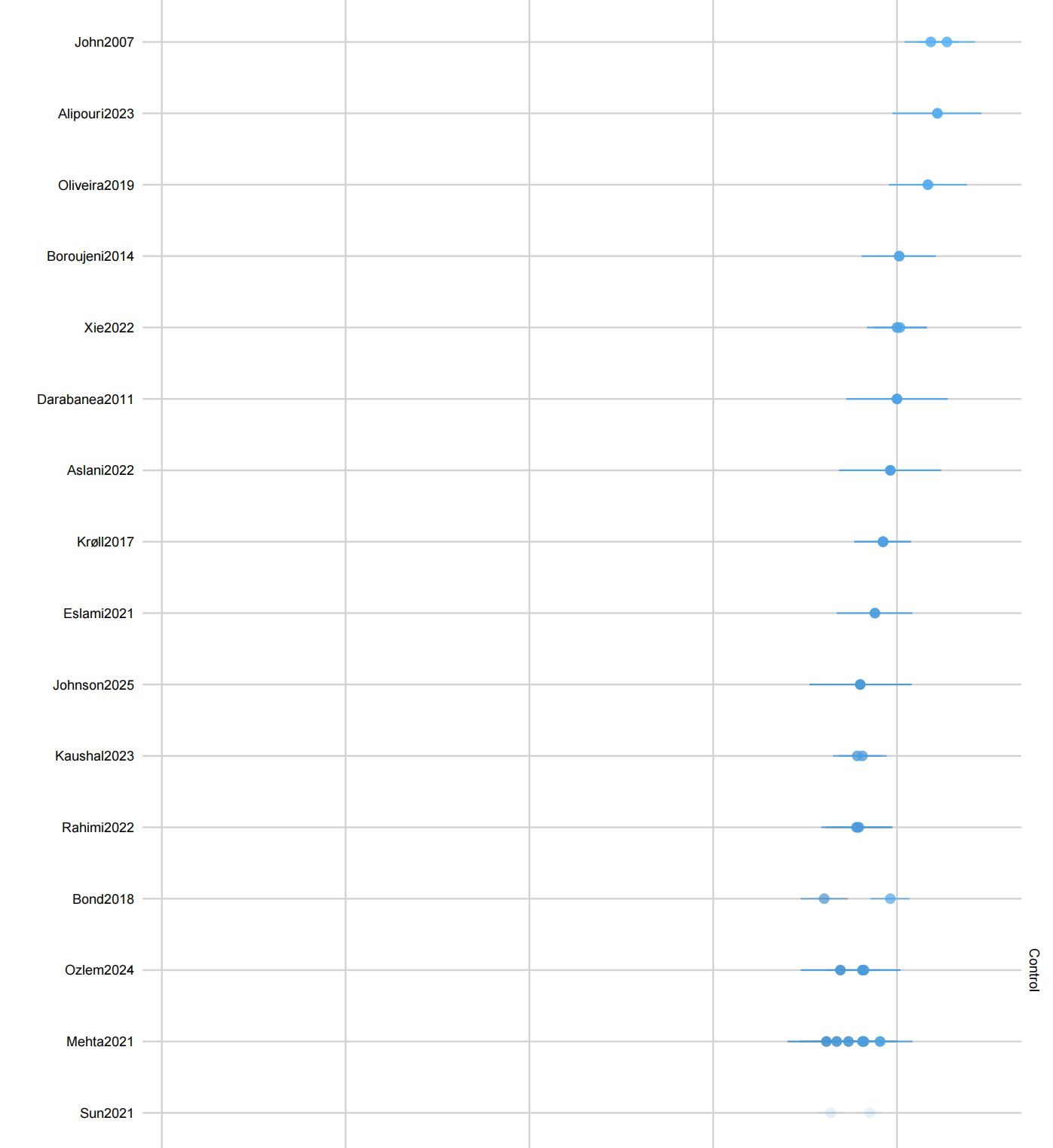


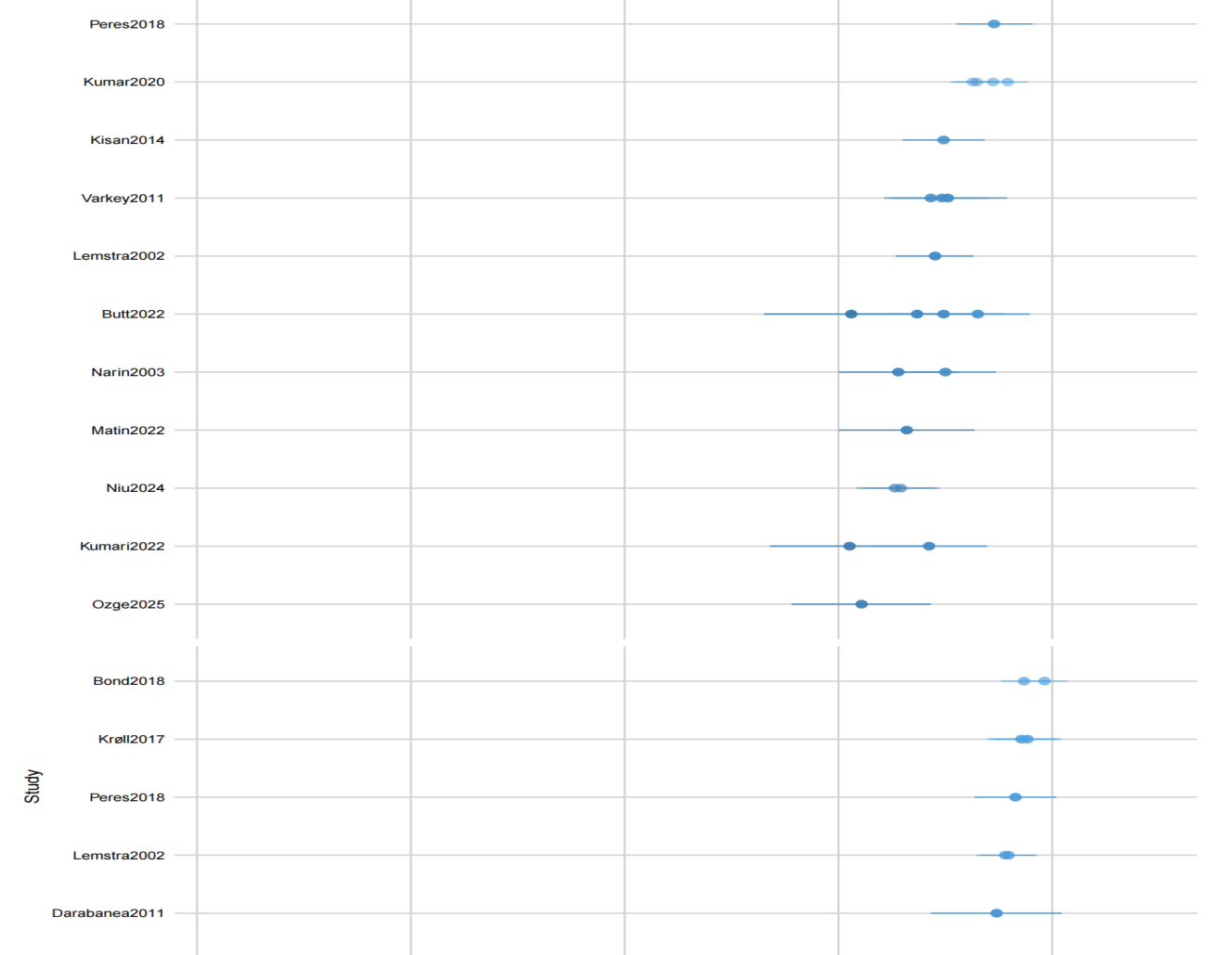
**Figure 5(c) Dose-response relationship of exercise intervention duration to migraine**

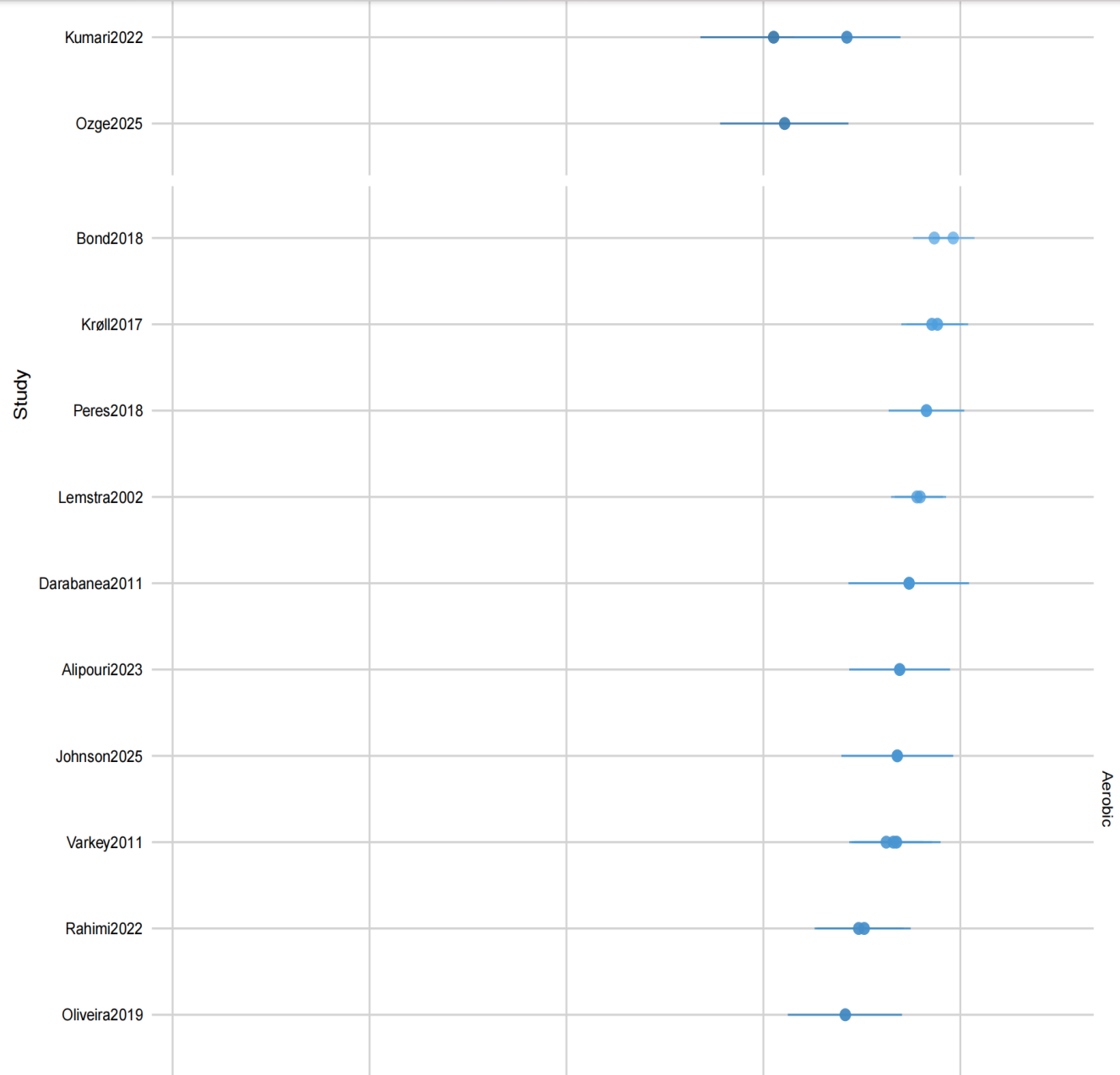


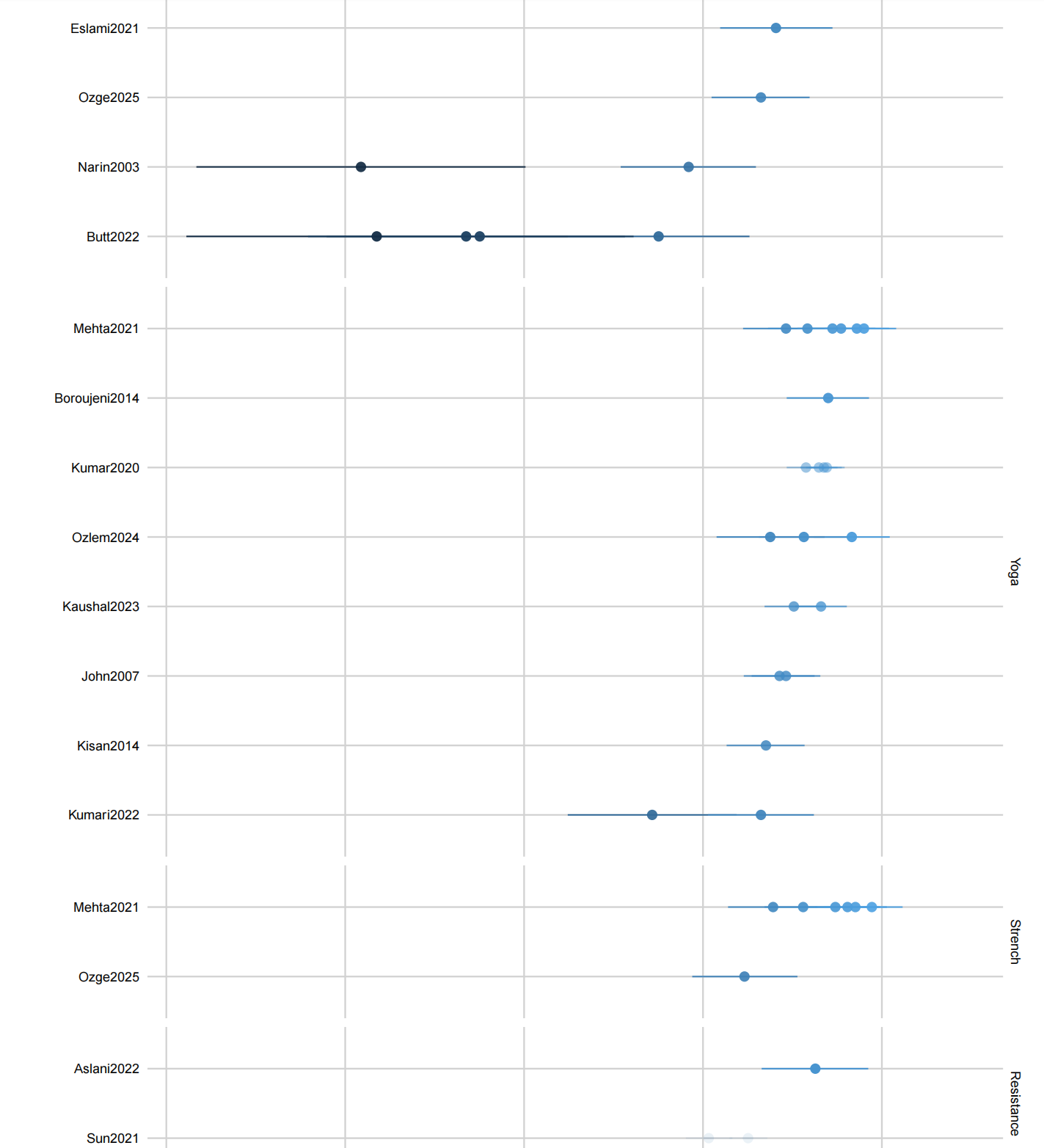
**Figure 5(d) Dose-response relationship of exercise follow-up period to migraine**

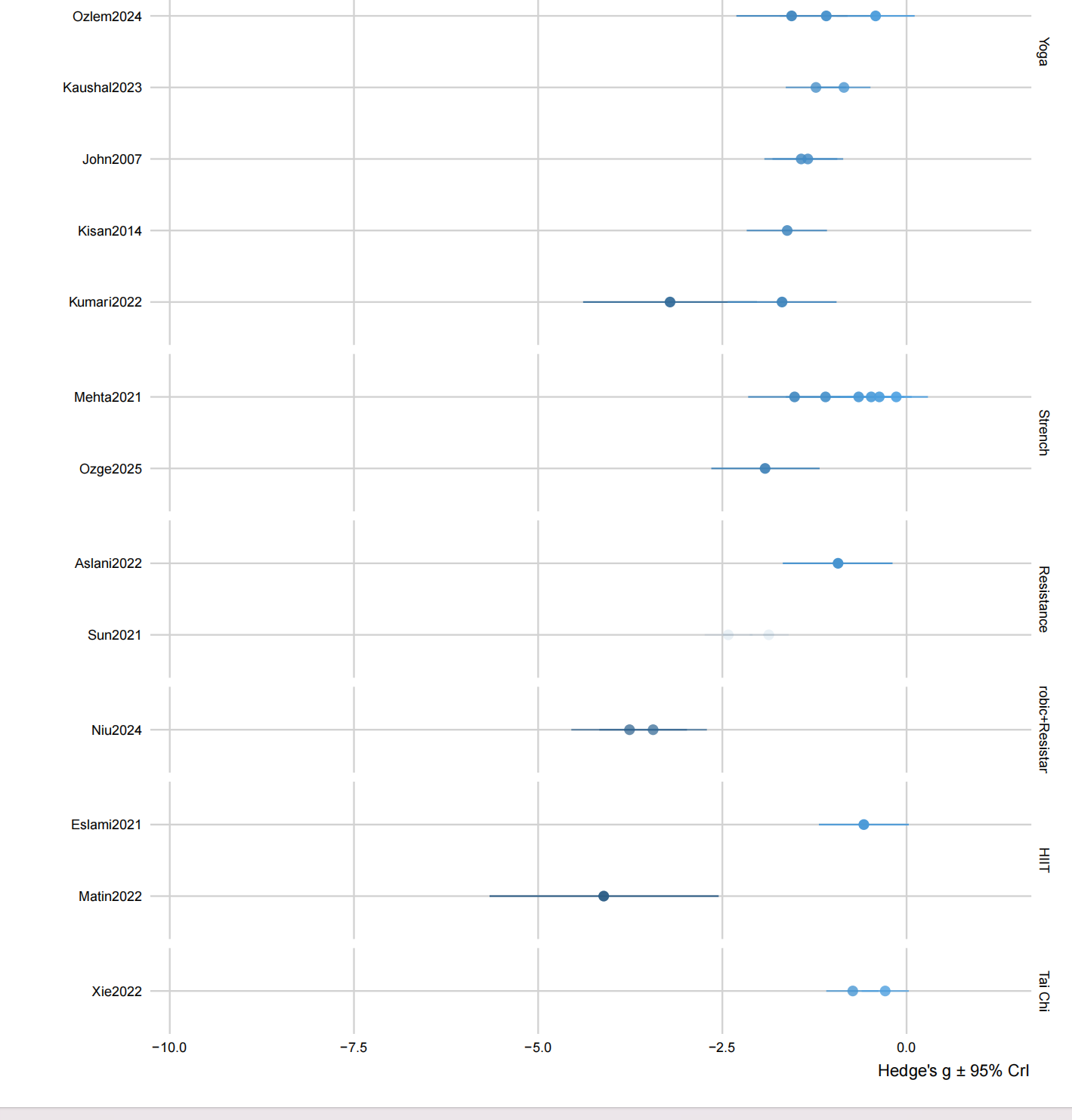
**Supplementary 10: Sample of arm-based forest plot**





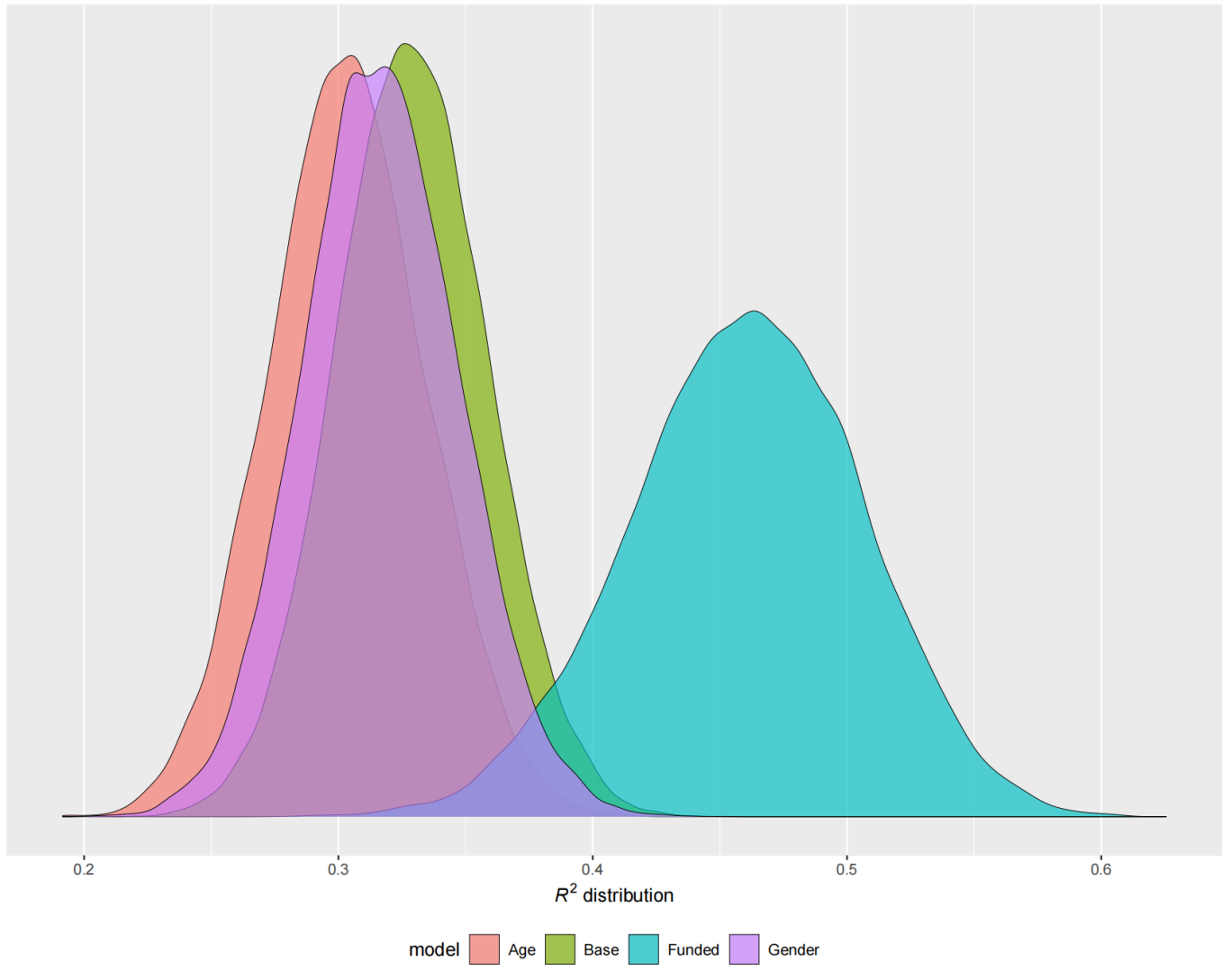






**Figure S6 Sample of arm-based forest plot**

**Supplementary 11: Model fitting effect**



**Figure S7 Density plots for R2 from models with interactions between treatment and moderators**

**Reference**

1. Alipouri M, Amiri E, Hoseini R, Hezarkhani LA. Effects of eight weeks of aerobic exercise and vitamin D supplementation on psychiatric comorbidities in men with migraine and vitamin D insufficiency: A randomized controlled clinical trial. J Affect Disord. 2023;334:12-20.

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