Apathy and Physical Activity: Meta-Analysis

Lahart IM, Boisgontier MP

5 de April, 2024

Contents

R Markdown file set-up

Packages required: 1) dmetar 2) tidyverse 3) meta 4) metafor 5) metasens 6) esc

Data file glimpse (not included in PDF)

Meta-analysis method

In a meta-analysis, we pooled Pearson product-moment correlations from eligible studies to examine the relationship between apathy and physical activity. Correlations were pooled using the generic inverse pooling method via the 'metacor' function in the R 'meta' package (Schwarzer et al., 2023a). This function automatically performs a necessary Fisher's z-transformation on the original, untransformed correlations prior to pooling. The 'metacor' function also reconverts the pooled association back to its original form for ease of interpretation. We used the 'metafor' package (Vietchbauer, 2010, 2023) to compare our three-level model to one in which a level was removed to investigate if our three-level model represented the variability in our data better than a two-level model. We anticipated considerable between-study heterogeneity, and therefore used a random-effects model to pool correlations. The restricted maximum likelihood (RML) estimator (Viechtbauer et al., 2005) was used to calculate the heterogeneity variance Tau2. In addition to Tau2, to quantify between study heterogeneity, we report the I2 statistic, which provides the percentage of variability in the correlations that is not caused by sampling error (Higgins et al., 2002). The I2 statistic was interpreted as follows: 0-40%, may not be important; 30-60%, may represent moderate heterogeneity; 50-90%, may represent substantial heterogeneity; and 75-100%, may represent considerable heterogeneity. To reduce the risk of false positives, we used a Knapp-Hartung adjustment (Knapp et al.,2003) to calculate the confidence interval around the pooled association. We also report the prediction interval, which provides a range within which we can expect the associations of future studies to fall based on the current evidence. The pooled correlation was interpreted using Cohen's conventions (Cohen et al., 1998): r -0.10, small negative correlation; r -0.30, moderate negative correlation; r -0.50, large negative correlation. Egger's regression test of funnel plot asymmetry (Egger et al., 1997) and a p-curve analysis (Simonsohn et al., 2014) were conducted to assess potential publication bias in our meta-analysis. The Rücker's limit meta-analysis method (Schwarzer et al., 2023b), which explicitly includes the heterogeneity variance in the model, was used to compute bias-corrected estimate of the true effect size.

A secondary meta-analysis was conducted using the same approach, but based on Spearman's rho values, to further test the relationship between apathy and physical activity.

Subgroup analyses were conducted to examine the differences in correlations between studies including participants with different health conditions and using different types of physical activity outcomes, and apathy measures.

Meta-regressions were conducted to examine if the average age of participants or the proportion of women in a study predicted the reported correlation between apathy and physical activity. Another meta-regression was used as a sensitivity analysis to examine whether the quality of the studies affected the correlation.

All analyses were performed in RStudio integrated development environment (IDE) (2023.06.1+524, "Mountain Hydrangea" release) for R software environment (R Core Team, 2023) using the 'meta' (Schwarzer, 2023a), 'metasens' (Schwarzer et al., 2023b), and 'metafor' (Vietchbauer, 2010, 2023) R packages.

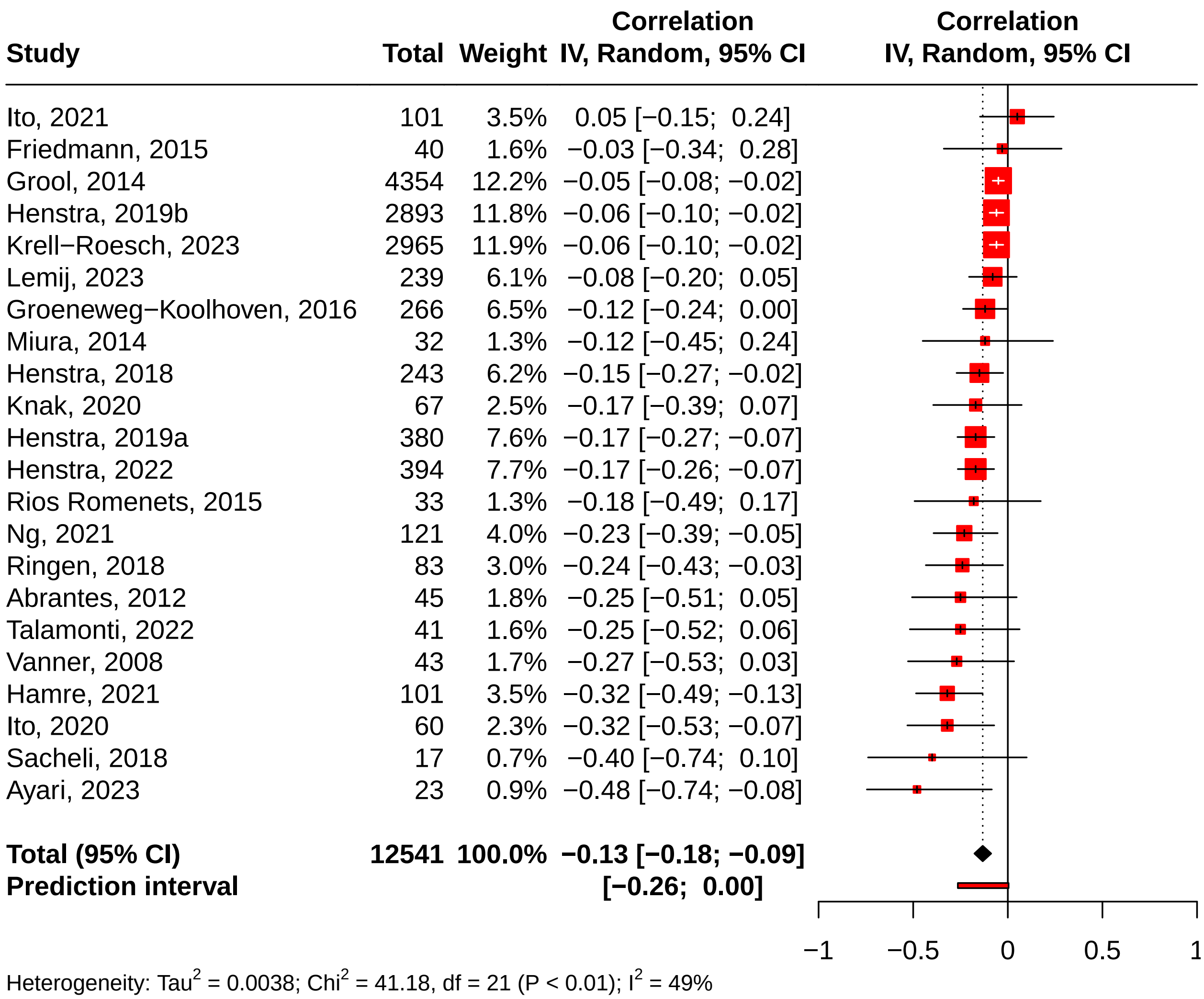
Meta-analysis: primary analysis

```r
m.cor <- metacor(cor = cor,
                 n = n,
                 studlab = author,
                 data = apathy_r,
                 fixed = FALSE,
                 random = TRUE,
                 method.tau = "REML",
                 hakn = TRUE,
                 title = "Apathy and physical activity behaviour")
summary(m.cor)
```

```
## Review:     Apathy and physical activity behaviour
##
##                               COR            95%-CI %W(random)
## Abrantes, 2012           -0.2500 [-0.5064;  0.0470]        1.8
## Ayari, 2023              -0.4800 [-0.7448; -0.0845]        0.9
## Friedmann, 2015          -0.0300 [-0.3383;  0.2842]        1.6
## Groeneweg-Koolhoven, 2016 -0.1200 [-0.2369;  0.0003]        6.5
## Hamre, 2021              -0.3200 [-0.4851; -0.1329]        3.5
## Ito, 2021                 0.0500 [-0.1469;  0.2431]        3.5
## Knak, 2020               -0.1700 [-0.3941;  0.0732]        2.5
## Lemij, 2023              -0.0800 [-0.2048;  0.0474]        6.1
## Ng, 2021                 -0.2300 [-0.3924; -0.0537]        4.0
## Ringen, 2018             -0.2400 [-0.4333; -0.0256]        3.0
## Rios Romenets, 2015      -0.1800 [-0.4929;  0.1741]        1.3
## Sacheli, 2018            -0.4000 [-0.7386;  0.0998]        0.7
## Talamonti, 2022          -0.2500 [-0.5178;  0.0625]        1.6
## Vanner, 2008             -0.2700 [-0.5276;  0.0330]        1.7
## Miura, 2014              -0.1200 [-0.4499;  0.2387]        1.3
## Henstra, 2018            -0.1500 [-0.2707; -0.0246]        6.2
## Ito, 2020                -0.3200 [-0.5308; -0.0719]        2.3
## Grool, 2014              -0.0500 [-0.0796; -0.0203]       12.2
## Henstra, 2019a           -0.1700 [-0.2661; -0.0706]        7.6
## Henstra, 2019b           -0.0600 [-0.0962; -0.0236]       11.8
## Henstra, 2022            -0.1700 [-0.2644; -0.0724]        7.7
## Krell-Roesch, 2023       -0.0600 [-0.0958; -0.0241]       11.9
##
## Number of studies: k = 22
## Number of observations: o = 12541
##
##                          COR            95%-CI     t  p-value
## Random effects model -0.1325 [-0.1765; -0.0879] -6.14 < 0.0001
##
## Quantifying heterogeneity:
##  tau^2 = 0.0038 [0.0003; 0.0167]; tau = 0.0619 [0.0184; 0.1294]
##  I^2 = 49.0% [16.4%; 68.9%]; H = 1.40 [1.09; 1.79]
##
## Test of heterogeneity:
##      Q d.f. p-value
##  41.18   21  0.0053
##
## Details on meta-analytical method:
## - Inverse variance method
## - Restricted maximum-likelihood estimator for tau^2
## - Q-Profile method for confidence interval of tau^2 and tau
## - Hartung-Knapp adjustment for random effects model (df = 21)
## - Fisher's z transformation of correlations
```

Our meta-analysis of 22 studies (n = 12,541) based on Pearson's r revealed a statistically significant small negative correlation between apathy and physical activity (r = -0.13; 95% confidence interval [95% CI]: -0.18 to -0.09; $p < 0.0001$). Further supporting this result, between-study statistical heterogeneity could be considered moderate (Tau2 = 0.0038, 95% CI: 0.0003 to 0.0167; I2 = 49.0%, 95% CI: 16.4 to 68.9%), and the prediction interval ranged from r = -0.26 to 0.00, suggesting that the correlation is expected to be negative for a future study.

```r
forest(m.cor,
            layout = "Revman5",
            sortvar = -TE,
            prediction = TRUE,
            print.tau2 = FALSE,
            leftlabs = c("Author", "n"),
            xlim=c(-1.0,1.0),
            fs.hetstat = 10,
            addrows.below.overall = 2)
```




```r
png(file = "Main analysis forestplot.png",
    width = 2800, height = 3800, res = 300)

forest(m.cor,
            layout = "Revman5",
            sortvar = -TE,
            prediction = TRUE,
            print.tau2 = FALSE,
            leftlabs = c("Author", "n"),
            xlim=c(-1.0,1.0),
            fs.hetstat = 10,
```

```r
            addrows.below.overall = 2)

dev.off()
```

```
## pdf
##   2
```

Secondary analysis based on Spearman's rho values

Analysis with metafor with model comparisons

```r
mv.cor.rho <- rma.mv(yi = z,
                V = var.z,
                slab = author,
                data = apathy_rho,
                random = ~ 1 | author/cor_id,
                test = "t",
                method = "REML")
summary(mv.cor.rho)
```

```
##
## Multivariate Meta-Analysis Model (k = 7; method: REML)
##
##   logLik  Deviance       AIC       BIC      AICc
##   1.3899   -2.7798    3.2202    2.5955   15.2202
##
## Variance Components:
##
##             estim    sqrt  nlvls  fixed         factor
## sigma^2.1  0.0973  0.3119      4     no         author
## sigma^2.2  0.0000  0.0000      7     no  author/cor_id
##
## Test for Heterogeneity:
## Q(df = 6) = 33.4420, p-val < .0001
##
## Model Results:
##
## estimate      se     tval  df    pval    ci.lb    ci.ub
##  -0.4275  0.1678  -2.5474   6  0.0436  -0.8381  -0.0169  *
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
round(convert_z2r(-0.4275), 3) # point estimate
```

```
## [1] -0.403
```

```r
round(convert_z2r(-0.8381), 3) # lower CI
```

```
## [1] -0.685
```

```r
round(convert_z2r(-0.0169), 3) # Upper CI
```

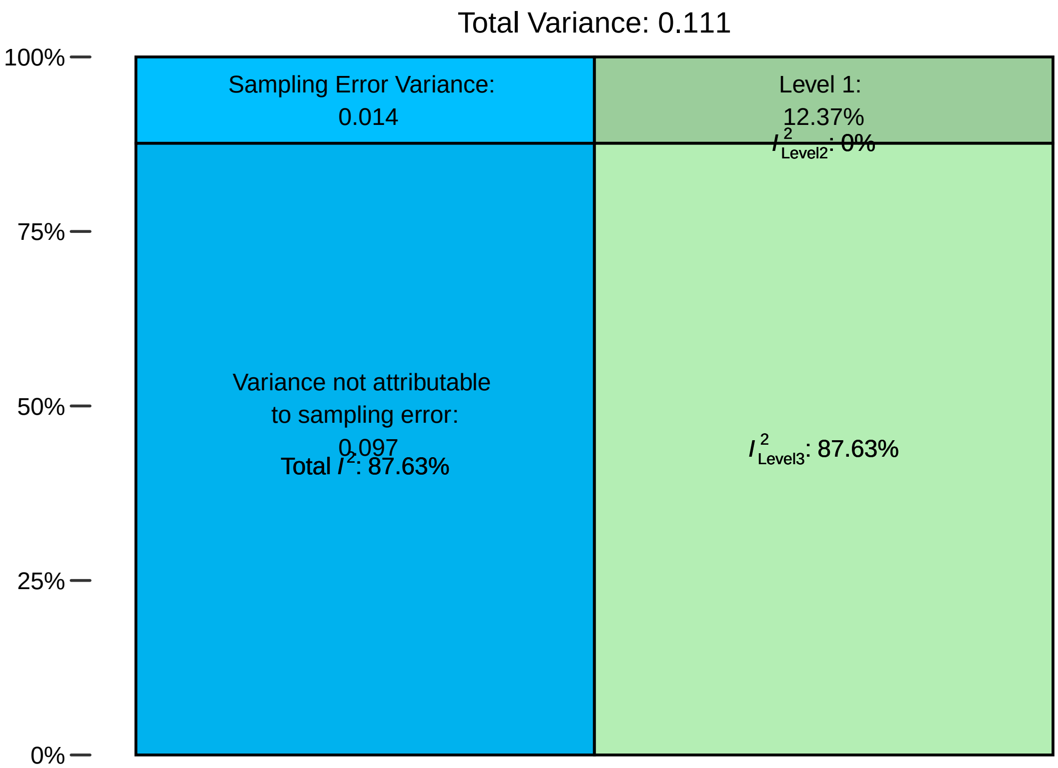
```
## [1] -0.017
```

Explore heterogeneity

```r
i2 <- var.comp(mv.cor.rho)
summary(i2)
```

```
##          % of total variance    I2
## Level 1         1.236966e+01   ---
## Level 2         3.468176e-09     0
## Level 3         8.763034e+01 87.63
## Total I2: 87.63%
```

```r
plot(i2)
```



Comparing models

Reduced model in which the level 3 variance (between study heterogeneity) is set to 0, which assumes all effect sizes are independent.

```r
l3.removed <- rma.mv(yi = z,
                     V = var.z,
                     slab = author,
                     data = apathy_rho,
                     random = ~ 1 | author/cor_id,
                     test = "t",
                     method = "REML",
                     sigma2 =  c(0, NA))

summary(l3.removed)
```

```
##
## Multivariate Meta-Analysis Model (k = 7; method: REML)
```

```
##
##   logLik  Deviance       AIC       BIC      AICc
##  -1.2868    2.5736    6.5736    6.1572   10.5736
##
## Variance Components:
##
##             estim    sqrt  nlvls  fixed         factor
## sigma^2.1  0.0000  0.0000      4    yes         author
## sigma^2.2  0.0716  0.2676      7     no  author/cor_id
##
## Test for Heterogeneity:
## Q(df = 6) = 33.4420, p-val < .0001
##
## Model Results:
##
## estimate      se     tval  df    pval    ci.lb    ci.ub
##  -0.3346  0.1116  -2.9987   6  0.0240  -0.6076  -0.0616  *
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Comparing full and reduced models.

```
anova(mv.cor.rho, l3.removed)
```

```
##
##         df    AIC    BIC    AICc  logLik    LRT   pval      QE
## Full     3 3.2202 2.5955 15.2202  1.3899               33.4420
## Reduced  2 6.5736 6.1572 10.5736 -1.2868 5.3535 0.0207 33.4420
```

Secondary analysis of rho values with meta

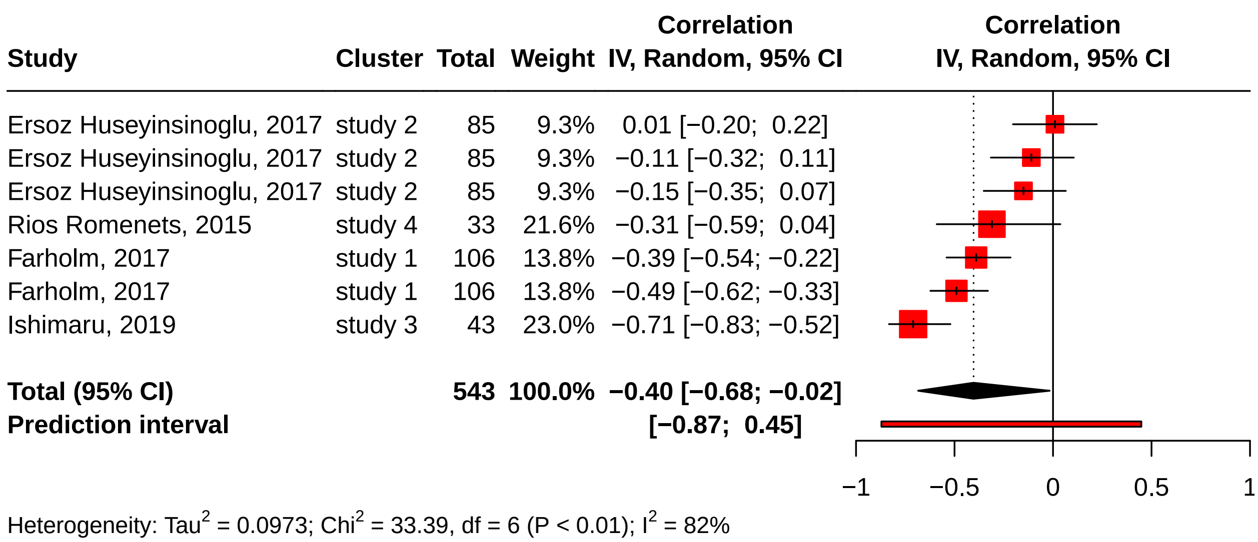
```
m.cor.rho <- metacor(cor = cor,
                 n = n,
                 data = apathy_rho,
                 cluster = cluster,
                 studlab = author,
                 fixed = FALSE,
                 random = TRUE,
                 method.tau = "REML",
                 hakn = TRUE)
summary(m.cor.rho)
```

```
##                                 COR             95%-CI %W(random) cluster
## Farholm, 2017               -0.4900 [-0.6226; -0.3301]       13.8 study 1
## Farholm, 2017               -0.3900 [-0.5405; -0.2153]       13.8 study 1
## Ersoz Huseyinsinoglu, 2017 -0.1500 [-0.3519;  0.0652]        9.3 study 2
## Ersoz Huseyinsinoglu, 2017  0.0100 [-0.2036;  0.2226]        9.3 study 2
## Ersoz Huseyinsinoglu, 2017 -0.1100 [-0.3157;  0.1056]        9.3 study 2
## Ishimaru, 2019              -0.7100 [-0.8328; -0.5207]       23.0 study 3
## Rios Romenets, 2015         -0.3100 [-0.5905;  0.0373]       21.6 study 4
##
## Number of studies: n = 4
## Number of estimates: k = 7
## Number of observations: o = 543
```

```
##
##                          COR            95%-CI      t p-value
## Random effects model -0.4033 [-0.6849; -0.0169] -2.55  0.0436
##
## Quantifying heterogeneity:
##  tau^2.1 = 0.0973 [0.0158; 0.9745]; tau.1 = 0.3119 [0.1259; 0.9872] (between cluster)
##  tau^2.2 < 0.0001 [0.0000; 0.0588]; tau.2 < 0.0001 [0.0000; 0.2424] (within cluster)
##  I^2 = 82.0% [64.1%; 91.0%]; H = 2.36 [1.67; 3.34]
##
## Test of heterogeneity:
##      Q d.f.  p-value
##  33.39    6 < 0.0001
##
## Details on meta-analytical method:
## - Inverse variance method (three-level model)
## - Restricted maximum-likelihood estimator for tau^2
## - Profile-Likelihood method for confidence interval of tau^2 and tau
## - Random effects confidence interval based on t-distribution (df = 6)
## - Fisher's z transformation of correlations
```

Results of the secondary meta-analysis based on seven Spearman rho values (k = 4, n = 543) were consistent with those based on Pearson's r as they showed a statistically significant moderate negative correlation between apathy and physical activity (r = -0.40; 95% CI: -0.68 to -0.02; p = 0.043). However, we observed substantial to considerable between-study statistical heterogeneity (between-cluster Tau2 = 0.09, 95% CI: 0.01 to 0.97; I2 = 82.0%, 95% CI: 64.1 to 91.0%), and the prediction interval ranged from r = -0.87 to 0.45, indicating that a moderate positive correlation cannot be ruled out for future studies.

```r
forest(m.cor.rho,
            layout = "Revman5",
            sortvar = -TE,
            prediction = TRUE,
            print.tau2 = FALSE,
            fontsize = 11,
            xlim=c(-1.0,1.0),
            fs.hetstat = 10,
            addrows.below.overall = 2)
```



```r
png(file = "Rho analysis forestplot.png",
    width = 2500, height = 2000, res = 300)

forest(m.cor.rho,
            layout = "Revman5",
            sortvar = -TE,
            prediction = TRUE,
            print.tau2 = FALSE,
            fontsize = 11,
            xlim=c(-1.0,1.0),
            fs.hetstat = 10,
            addrows.below.overall = 2)

dev.off()
```

```
## pdf
##   2
```

Meta-analysis: subgroup analyses

Subgroup analysis by health status

```r
apathy_r$Health_status <- as.factor(apathy_r$Health_status)

Health_subg <- update(m.cor,
            subgroup = Health_status,
            tau.common = FALSE)
Health_subg
```

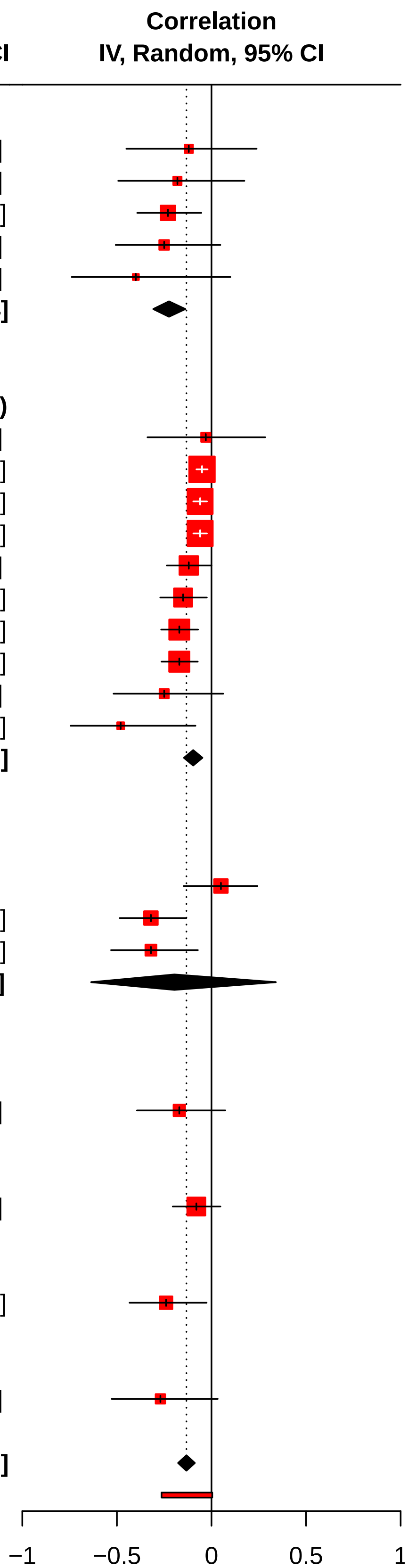
```
## Review:     Apathy and physical activity behaviour
##
## Number of studies: k = 22
## Number of observations: o = 12541
##
##                             COR              95%-CI     t  p-value
## Random effects model -0.1325 [-0.1765; -0.0879] -6.14 < 0.0001
##
## Quantifying heterogeneity:
##  tau^2 = 0.0038 [0.0003; 0.0167]; tau = 0.0619 [0.0184; 0.1294]
##  I^2 = 49.0% [16.4%; 68.9%]; H = 1.40 [1.09; 1.79]
##
## Test of heterogeneity:
##      Q d.f. p-value
##  41.18   21  0.0053
##
## Results for subgroups (random effects model):
##                                                       k     COR
## Health_status = Parkinson's disease                   5 -0.2246
## Health_status = Older adults (healthy, depressi ...  10 -0.0968
## Health_status = Stroke                                3 -0.1960
## Health_status = Myotonic dystrophy                    1 -0.1700
## Health_status = Cancer                                1 -0.0800
## Health_status = Severe mental illness                 1 -0.2400
```

```
## Health_status = Multiple sclerosis                      1 -0.2700
##                                                                95%-CI  tau^2
## Health_status = Parkinson's disease                  [-0.3078; -0.1381]      0
## Health_status = Older adults (healthy, depressi ... [-0.1455; -0.0476] 0.0018
## Health_status = Stroke                               [-0.6363;  0.3406] 0.0385
## Health_status = Myotonic dystrophy                   [-0.3941;  0.0732]     --
## Health_status = Cancer                               [-0.2048;  0.0474]     --
## Health_status = Severe mental illness                [-0.4333; -0.0256]     --
## Health_status = Multiple sclerosis                   [-0.5276;  0.0330]     --
##                                                         tau     Q   I^2
## Health_status = Parkinson's disease                       0  0.97  0.0%
## Health_status = Older adults (healthy, depressi ... 0.0418 17.94 49.8%
## Health_status = Stroke                               0.1961  8.75 77.1%
## Health_status = Myotonic dystrophy                       --  0.00    --
## Health_status = Cancer                                   --  0.00    --
## Health_status = Severe mental illness                    --  0.00    --
## Health_status = Multiple sclerosis                       --  0.00    --
##
## Test for subgroup differences (random effects model):
##                    Q d.f. p-value
## Between groups 14.13    6  0.0282
##
## Details on meta-analytical method:
## - Inverse variance method
## - Restricted maximum-likelihood estimator for tau^2
## - Q-Profile method for confidence interval of tau^2 and tau
## - Hartung-Knapp adjustment for random effects model (df = 21)
## - Fisher's z transformation of correlations
```

The test of subgroup differences between health status was possible between studies comprising older adults who were healthy, depressed, fallers, or had mild cognitive impairment (k = 10), people with Parkinson's Disease (k = 5), and stroke survivors (k = 3). We found statistical difference between these studies ($p < 0.0001$) (Table 2; Figure 6). The relationship between apathy and physical activity was statistically significant in studies that included older adults who were healthy, depressed, fallers, or had mild cognitive impairment (r = -0.10; 95% CI: -0.15 to -0.05) or patients with Parkinson's disease (r = -0.22; 95% CI: -0.31 to -0.14), but not in studies that included stroke survivors (r = -0.20; 95% CI: -0.64 to -0.34). However, statistical power was lacking in the latter (k = 3) and other health status (k = 1).

```r
forest(Health_subg,
            layout = "Revman",
            sortvar = -TE,
            common = FALSE,
            xlim = c(-1, 1),
            prediction = TRUE,
            fontsize = 11,
            fs.hetstat = 10,
            col.subgroup = 'black',
            addrows.below.overall = 2)
```

Study or Subgroup	Total	Weight	Correlation IV, Random, 95% CI
Health_status = Parkinson's disease			
Miura, 2014	32	1.3%	−0.12 [−0.45; 0.24]
Rios Romenets, 2015	33	1.3%	−0.18 [−0.49; 0.17]
Ng, 2021	121	4.0%	−0.23 [−0.39; −0.05]
Abrantes, 2012	45	1.8%	−0.25 [−0.51; 0.05]
Sacheli, 2018	17	0.7%	−0.40 [−0.74; 0.10]
Total (95% CI)	**248**	**9.1%**	**−0.22 [−0.31; −0.14]**
Heterogeneity: $Tau^2 = 0$; $Chi^2 = 0.97$, df = 4 (P = 0.91); $I^2 = 0\%$			
Health_status = Older adults (healthy, depression, falls, or MCI)			
Friedmann, 2015	40	1.6%	−0.03 [−0.34; 0.28]
Grool, 2014	4354	12.2%	−0.05 [−0.08; −0.02]
Henstra, 2019b	2893	11.8%	−0.06 [−0.10; −0.02]
Krell−Roesch, 2023	2965	11.9%	−0.06 [−0.10; −0.02]
Groeneweg−Koolhoven, 2016	266	6.5%	−0.12 [−0.24; 0.00]
Henstra, 2018	243	6.2%	−0.15 [−0.27; −0.02]
Henstra, 2019a	380	7.6%	−0.17 [−0.27; −0.07]
Henstra, 2022	394	7.7%	−0.17 [−0.26; −0.07]
Talamonti, 2022	41	1.6%	−0.25 [−0.52; 0.06]
Ayari, 2023	23	0.9%	−0.48 [−0.74; −0.08]
Total (95% CI)	**11599**	**68.1%**	**−0.10 [−0.15; −0.05]**
Heterogeneity: $Tau^2 = 0.0018$; $Chi^2 = 17.94$, df = 9 (P = 0.04); $I^2 = 50\%$			
Health_status = Stroke			
Ito, 2021	101	3.5%	0.05 [−0.15; 0.24]
Hamre, 2021	101	3.5%	−0.32 [−0.49; −0.13]
Ito, 2020	60	2.3%	−0.32 [−0.53; −0.07]
Total (95% CI)	**262**	**9.4%**	**−0.20 [−0.64; 0.34]**
Heterogeneity: $Tau^2 = 0.0385$; $Chi^2 = 8.75$, df = 2 (P = 0.01); $I^2 = 77\%$			
Health_status = Myotonic dystrophy			
Knak, 2020	67	2.5%	−0.17 [−0.39; 0.07]
Health_status = Cancer			
Lemij, 2023	239	6.1%	−0.08 [−0.20; 0.05]
Health_status = Severe mental illness			
Ringen, 2018	83	3.0%	−0.24 [−0.43; −0.03]
Health_status = Multiple sclerosis			
Vanner, 2008	43	1.7%	−0.27 [−0.53; 0.03]
Total (95% CI)	**12541**	**100.0%**	**−0.13 [−0.18; −0.09]**
Prediction interval			**[−0.26; 0.00]**



Heterogeneity: $Tau^2 = 0.0038$; $Chi^2 = 41.18$, df = 21 (P < 0.01); $I^2 = 49\%$
Test for subgroup differences: $Chi^2 = 14.13$, df = 6 (P = 0.03)

```r
png(file = "Health condition forestplot.png",
    width = 2800, height = 3000, res = 300)

forest(Health_subg,
            layout = "Revman",
            sortvar = -TE,
            common = FALSE,
            xlim = c(-1, 1),
            prediction = TRUE,
            fontsize = 11,
            fs.hetstat = 10,
            col.subgroup = 'black',
            addrows.below.overall = 2)

dev.off()
```

```
## pdf
##   2
```

Subgroup analysis by physical activity measurement instruments

Subgroup analysis by physical activity outcome

```r
apathy_r$PA_outcome <- as.factor(apathy_r$PA_outcome)

PAout_subg <- update(m.cor,
            subgroup = PA_outcome,
            tau.common = FALSE)
PAout_subg
```

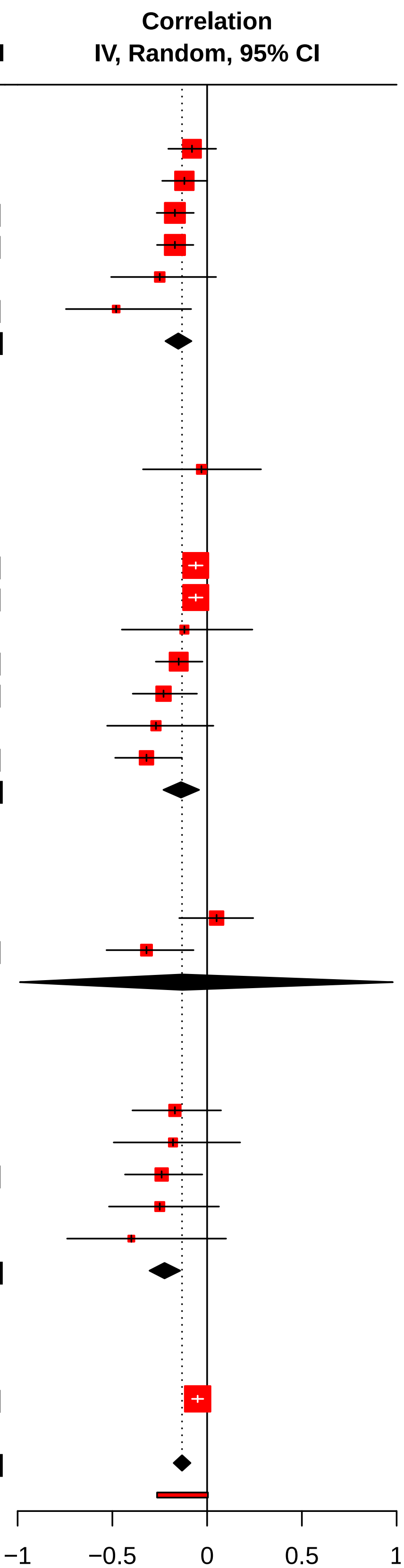
```
## Review:     Apathy and physical activity behaviour
##
## Number of studies: k = 22
## Number of observations: o = 12541
##
##                             COR            95%-CI     t  p-value
## Random effects model -0.1325 [-0.1765; -0.0879] -6.14 < 0.0001
##
## Quantifying heterogeneity:
##  tau^2 = 0.0038 [0.0003; 0.0167]; tau = 0.0619 [0.0184; 0.1294]
##  I^2 = 49.0% [16.4%; 68.9%]; H = 1.40 [1.09; 1.79]
##
## Test of heterogeneity:
##      Q d.f. p-value
##  41.18   21  0.0053
##
## Results for subgroups (random effects model):
##                                k     COR             95%-CI   tau^2    tau     Q
## PA_outcome = MET-min/week   6 -0.1521 [-0.2200; -0.0827] <0.0001 0.0021  4.97
## PA_outcome = Kcal/day       1 -0.0300 [-0.3383;  0.2842]      --     --  0.00
## PA_outcome = Score          7 -0.1377 [-0.2305; -0.0425]  0.0065 0.0803 13.79
## PA_outcome = Steps/day      2 -0.1304 [-0.9880;  0.9797]  0.0590 0.2428  5.25
## PA_outcome = Active time    5 -0.2247 [-0.3040; -0.1423]       0      0  0.85
## PA_outcome = Frequency      1 -0.0500 [-0.0796; -0.0203]      --     --  0.00
```

```
##                             I^2
## PA_outcome = MET-min/week  0.0%
## PA_outcome = Kcal/day        --
## PA_outcome = Score        56.5%
## PA_outcome = Steps/day    81.0%
## PA_outcome = Active time   0.0%
## PA_outcome = Frequency       --
##
## Test for subgroup differences (random effects model):
##                    Q d.f.  p-value
## Between groups 33.31    5 < 0.0001
##
## Details on meta-analytical method:
## - Inverse variance method
## - Restricted maximum-likelihood estimator for tau^2
## - Q-Profile method for confidence interval of tau^2 and tau
## - Hartung-Knapp adjustment for random effects model (df = 21)
## - Fisher's z transformation of correlations
```

The test of subgroup differences between physical activity outcomes was possible between studies using a score from a questionnaire (k = 7), MET-min/week (k = 6), active time per day or week (k = 5), and steps per day (k = 2) (Table 2; Figure 7). We found statistical difference between these studies ($p < 0.0001$). The relationship between apathy and physical activity was statistically significant in studies using a score (r = -0.14; 95% CI: -0.23 to -0.04), MET-min/week (r = -0.15; 95% CI: -0.22 to -0.08), and active time (r = -0.22; 95% CI: -0.30 to -0.14), but not in studies that used the number of steps per day (r = -0.13; 95% CI: -0.99 to 0.98). However, statistical power was lacking in the latter (k = 2) and other physical activity outcomes (k = 1).

```r
forest(PAout_subg,
            layout = "RevMan5",
            sortvar = -TE,
            common = FALSE,
            xlim = c(-1.0, 1.0),
            prediction = TRUE,
            fontsize = 11,
            fs.hetstat = 10,
            col.subgroup = 'black',
            addrows.below.overall = 2)
```

Study or Subgroup	Total	Weight	Correlation IV, Random, 95% CI
PA_outcome = MET−min/week			
Lemij, 2023	239	6.1%	−0.08 [−0.20; 0.05]
Groeneweg−Koolhoven, 2016	266	6.5%	−0.12 [−0.24; 0.00]
Henstra, 2019a	380	7.6%	−0.17 [−0.27; −0.07]
Henstra, 2022	394	7.7%	−0.17 [−0.26; −0.07]
Abrantes, 2012	45	1.8%	−0.25 [−0.51; 0.05]
Ayari, 2023	23	0.9%	−0.48 [−0.74; −0.08]
Total (95% CI)	**1347**	**30.7%**	**−0.15 [−0.22; −0.08]**
Heterogeneity: Tau^2 = < 0.0001; Chi^2 = 4.97, df = 5 (P = 0.42); I^2 = 0%			
PA_outcome = Kcal/day			
Friedmann, 2015	40	1.6%	−0.03 [−0.34; 0.28]
PA_outcome = Score			
Henstra, 2019b	2893	11.8%	−0.06 [−0.10; −0.02]
Krell−Roesch, 2023	2965	11.9%	−0.06 [−0.10; −0.02]
Miura, 2014	32	1.3%	−0.12 [−0.45; 0.24]
Henstra, 2018	243	6.2%	−0.15 [−0.27; −0.02]
Ng, 2021	121	4.0%	−0.23 [−0.39; −0.05]
Vanner, 2008	43	1.7%	−0.27 [−0.53; 0.03]
Hamre, 2021	101	3.5%	−0.32 [−0.49; −0.13]
Total (95% CI)	**6398**	**40.5%**	**−0.14 [−0.23; −0.04]**
Heterogeneity: Tau^2 = 0.0065; Chi^2 = 13.79, df = 6 (P = 0.03); I^2 = 56%			
PA_outcome = Steps/day			
Ito, 2021	101	3.5%	0.05 [−0.15; 0.24]
Ito, 2020	60	2.3%	−0.32 [−0.53; −0.07]
Total (95% CI)	**161**	**5.8%**	**−0.13 [−0.99; 0.98]**
Heterogeneity: Tau^2 = 0.0590; Chi^2 = 5.25, df = 1 (P = 0.02); I^2 = 81%			
PA_outcome = Active time			
Knak, 2020	67	2.5%	−0.17 [−0.39; 0.07]
Rios Romenets, 2015	33	1.3%	−0.18 [−0.49; 0.17]
Ringen, 2018	83	3.0%	−0.24 [−0.43; −0.03]
Talamonti, 2022	41	1.6%	−0.25 [−0.52; 0.06]
Sacheli, 2018	17	0.7%	−0.40 [−0.74; 0.10]
Total (95% CI)	**241**	**9.2%**	**−0.22 [−0.30; −0.14]**
Heterogeneity: Tau^2 = 0; Chi^2 = 0.85, df = 4 (P = 0.93); I^2 = 0%			
PA_outcome = Frequency			
Grool, 2014	4354	12.2%	−0.05 [−0.08; −0.02]
Total (95% CI)	**12541**	**100.0%**	**−0.13 [−0.18; −0.09]**
Prediction interval			**[−0.26; 0.00]**



Heterogeneity: Tau^2 = 0.0038; Chi^2 = 41.18, df = 21 (P < 0.01); I^2 = 49%
Test for subgroup differences: Chi^2 = 33.31, df = 5 (P < 0.01)

```r
png(file = "PA outcome forestplot.png",
    width = 2800, height = 3200, res = 300)

forest(PAout_subg,
             layout = "RevMan5",
            sortvar = -TE,
            common = FALSE,
            xlim = c(-1.0, 1.0),
            prediction = TRUE,
            fontsize = 11,
            fs.hetstat = 10,
            col.subgroup = 'black',
            addrows.below.overall = 2)

dev.off()
```

```
## pdf
##   2
```

Subgroup analysis by apathy measure

```r
apathy_r$Apathy <- as.factor(apathy_r$Apathy)

apathy_subg <- update(m.cor,
            subgroup = Apathy,
            tau.common = FALSE)
apathy_subg
```

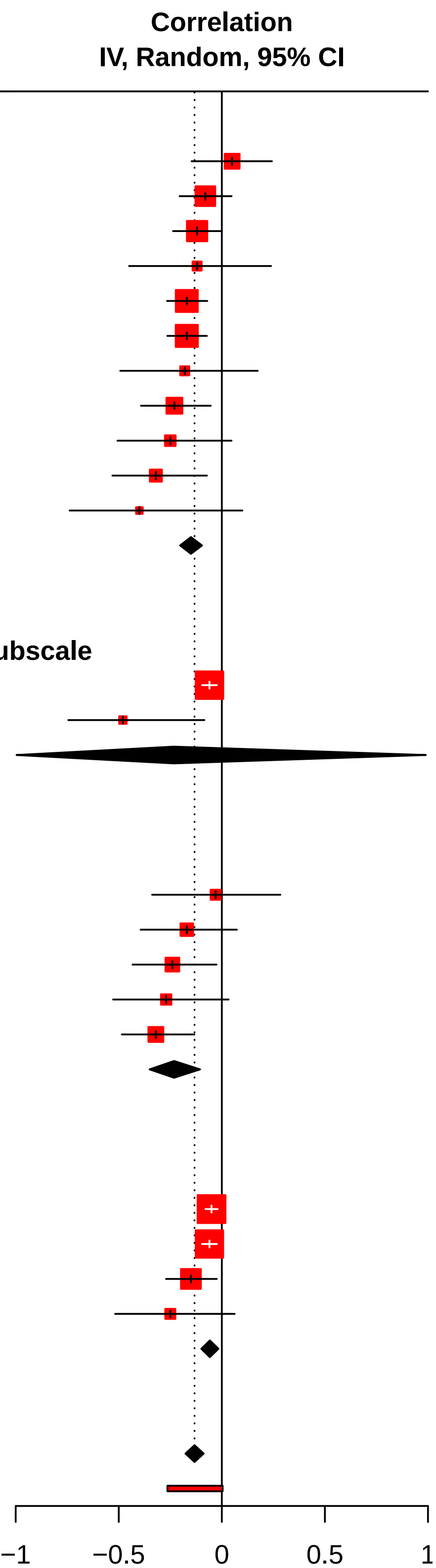
```
## Review:     Apathy and physical activity behaviour
##
## Number of studies: k = 22
## Number of observations: o = 12541
##
##                         COR             95%-CI     t  p-value
## Random effects model -0.1325 [-0.1765; -0.0879] -6.14 < 0.0001
##
## Quantifying heterogeneity:
##  tau^2 = 0.0038 [0.0003; 0.0167]; tau = 0.0619 [0.0184; 0.1294]
##  I^2 = 49.0% [16.4%; 68.9%]; H = 1.40 [1.09; 1.79]
##
## Test of heterogeneity:
##      Q d.f. p-value
##  41.18   21  0.0053
##
## Results for subgroups (random effects model):
##                                                 k     COR             95%-CI
## Apathy = Apathy Scale (AS)                     11 -0.1498 [-0.2027; -0.0960]
## Apathy = Neuropsychiatric Inventory Ques ...    2 -0.2335 [-0.9959;  0.9895]
## Apathy = Apathy Evaluation Scale (AES)          5 -0.2316 [-0.3505; -0.1054]
## Apathy = Geriatric Depression Scale - Ap ...    4 -0.0581 [-0.0996; -0.0165]
##                                                 tau^2    tau     Q   I^2
## Apathy = Apathy Scale (AS)                          0      0 9.95  0.0%
## Apathy = Neuropsychiatric Inventory Ques ...   0.0820 0.2863 4.26 76.5%
## Apathy = Apathy Evaluation Scale (AES)              0      0 2.80  0.0%
```

```
## Apathy = Geriatric Depression Scale - Ap ... <0.0001 0.0016 3.85 22.1%
##
## Test for subgroup differences (random effects model):
##                    Q d.f.  p-value
## Between groups 22.14    3 < 0.0001
##
## Details on meta-analytical method:
## - Inverse variance method
## - Restricted maximum-likelihood estimator for tau^2
## - Q-Profile method for confidence interval of tau^2 and tau
## - Hartung-Knapp adjustment for random effects model (df = 21)
## - Fisher's z transformation of correlations
```

The test of subgroup differences between apathy measures was possible between studies using the Apathy Scale (k = 11), the Apathy Evaluation Scale (k = 5), the apathy subscale of the Geriatric Depression Scale (k = 4), and the apathy subscale of the Neuropsychiatric Inventory Questionnaire (k = 2) (Table 2; Figure 8). The relationship between apathy and physical activity was statistically significant in studies using the Apathy Scale (r = -0.14; 95% CI: -0.23 to -0.04), Apathy Evaluation Scale (r = -0.15; 95% CI: -0.22 to -0.08), and Geriatric Depression Scale (r = -0.22; 95% CI: -0.30 to -0.14), but not in studies that used the Neuropsychiatric Inventory Questionnaire (r = -0.13; 95% CI: -0.99 to 0.98). However, statistical power was lacking in the latter apathy measure (k = 2).

```
forest(apathy_subg,
            layout = "Revman5",
            sortvar = -TE,
            common = FALSE,
            xlim = c(-1, 1),
            prediction = TRUE,
            fontsize = 11,
            fs.hetstat = 10,
            col.subgroup = 'black',
            addrows.below.overall = 2)
```

Study or Subgroup	Total	Weight	Correlation IV, Random, 95% CI
Apathy = Apathy Scale (AS)			
Ito, 2021	101	3.5%	0.05 [−0.15; 0.24]
Lemij, 2023	239	6.1%	−0.08 [−0.20; 0.05]
Groeneweg−Koolhoven, 2016	266	6.5%	−0.12 [−0.24; 0.00]
Miura, 2014	32	1.3%	−0.12 [−0.45; 0.24]
Henstra, 2019a	380	7.6%	−0.17 [−0.27; −0.07]
Henstra, 2022	394	7.7%	−0.17 [−0.26; −0.07]
Rios Romenets, 2015	33	1.3%	−0.18 [−0.49; 0.17]
Ng, 2021	121	4.0%	−0.23 [−0.39; −0.05]
Abrantes, 2012	45	1.8%	−0.25 [−0.51; 0.05]
Ito, 2020	60	2.3%	−0.32 [−0.53; −0.07]
Sacheli, 2018	17	0.7%	−0.40 [−0.74; 0.10]
Total (95% CI)	**1688**	**42.9%**	**−0.15 [−0.20; −0.10]**
Heterogeneity: $Tau^2 = 0$; $Chi^2 = 9.95$, df = 10 (P = 0.45); $I^2 = 0\%$			
Apathy = Neuropsychiatric Inventory Questionnaire − Apathy subscale			
Krell−Roesch, 2023	2965	11.9%	−0.06 [−0.10; −0.02]
Ayari, 2023	23	0.9%	−0.48 [−0.74; −0.08]
Total (95% CI)	**2988**	**12.8%**	**−0.23 [−1.00; 0.99]**
Heterogeneity: $Tau^2 = 0.0820$; $Chi^2 = 4.26$, df = 1 (P = 0.04); $I^2 = 77\%$			
Apathy = Apathy Evaluation Scale (AES)			
Friedmann, 2015	40	1.6%	−0.03 [−0.34; 0.28]
Knak, 2020	67	2.5%	−0.17 [−0.39; 0.07]
Ringen, 2018	83	3.0%	−0.24 [−0.43; −0.03]
Vanner, 2008	43	1.7%	−0.27 [−0.53; 0.03]
Hamre, 2021	101	3.5%	−0.32 [−0.49; −0.13]
Total (95% CI)	**334**	**12.4%**	**−0.23 [−0.35; −0.11]**
Heterogeneity: $Tau^2 = 0$; $Chi^2 = 2.8$, df = 4 (P = 0.59); $I^2 = 0\%$			
Apathy = Geriatric Depression Scale − Apathy subscale			
Grool, 2014	4354	12.2%	−0.05 [−0.08; −0.02]
Henstra, 2019b	2893	11.8%	−0.06 [−0.10; −0.02]
Henstra, 2018	243	6.2%	−0.15 [−0.27; −0.02]
Talamonti, 2022	41	1.6%	−0.25 [−0.52; 0.06]
Total (95% CI)	**7531**	**31.9%**	**−0.06 [−0.10; −0.02]**
Heterogeneity: $Tau^2 = < 0.0001$; $Chi^2 = 3.85$, df = 3 (P = 0.28); $I^2 = 22\%$			
Total (95% CI)	**12541**	**100.0%**	**−0.13 [−0.18; −0.09]**
Prediction interval			**[−0.26; 0.00]**



Heterogeneity: $Tau^2 = 0.0038$; $Chi^2 = 41.18$, df = 21 (P < 0.01); $I^2 = 49\%$
Test for subgroup differences: $Chi^2 = 22.14$, df = 3 (P < 0.01)

```r
png(file = "Apathy measure forestplot.png",
    width = 2800, height = 3200, res = 300)

forest(apathy_subg,
            layout = "Revman5",
            sortvar = -TE,
            common = FALSE,
            xlim = c(-1, 1),
            prediction = TRUE,
            fontsize = 11,
            fs.hetstat = 10,
            col.subgroup = 'black',
            addrows.below.overall = 2)

dev.off()
```

```
## pdf
##   2
```

Meta-analysis: meta-regression

Meta-regression by age

```r
m.cor.reg.age <- metareg(m.cor, ~Age)
```

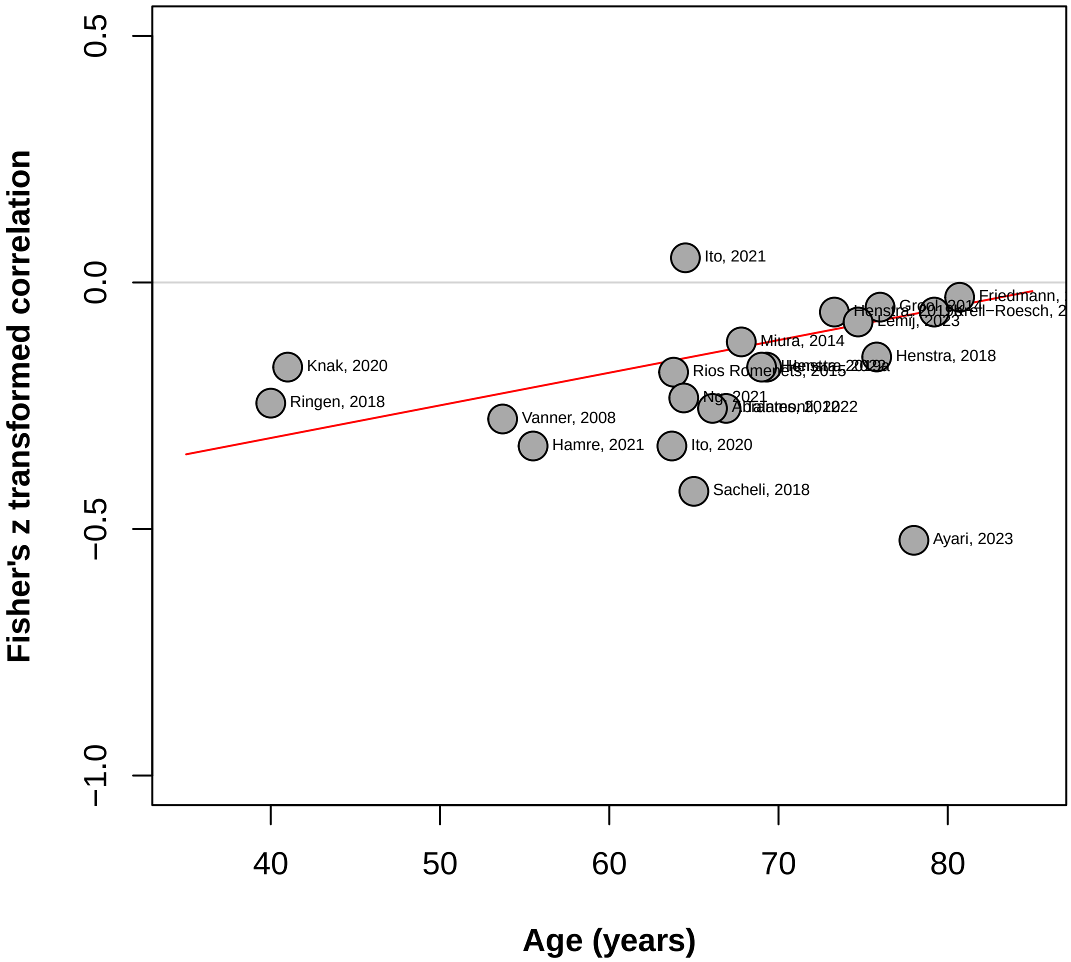
```
## Warning: 1 study with NAs omitted from model fitting.
```

```r
m.cor.reg.age
```

```
##
## Mixed-Effects Model (k = 21; tau^2 estimator: REML)
##
## tau^2 (estimated amount of residual heterogeneity):     0.0006 (SE = 0.0009)
## tau (square root of estimated tau^2 value):             0.0246
## I^2 (residual heterogeneity / unaccounted variability): 21.25%
## H^2 (unaccounted variability / sampling variability):   1.27
## R^2 (amount of heterogeneity accounted for):            86.58%
##
## Test for Residual Heterogeneity:
## QE(df = 19) = 24.4507, p-val = 0.1794
##
## Test of Moderators (coefficient 2):
## F(df1 = 1, df2 = 19) = 11.6081, p-val = 0.0030
##
## Model Results:
##
##          estimate      se     tval  df    pval    ci.lb    ci.ub
## intrcpt   -0.5802  0.1423  -4.0781  19  0.0006  -0.8780  -0.2824  ***
## Age        0.0066  0.0019   3.4071  19  0.0030   0.0026   0.0107   **
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Age statistically influenced the correlation values of the meta-analysis studies (k = 13; p = 0.003).

```r
Age.bubble <- bubble(m.cor.reg.age,
                     xlim = c(35, 85),
                     ylim = c(-1.0, 0.5),
                     xlab = 'Age (years)',
                     font.lab = 2,
                     studlab = TRUE,
                     cex = 2,
                     cex.studlab = 0.5,
                     pos.studlab = 4,
                     offset = 0.5,
                     col.line = 'red')
```




```r
Age.bubble
```

```
## NULL
```

```r
png(file = "Bubble plot for meta-regression by age.png",
    width = 2500, height = 2500, res = 300)

Age.bubble
```

```
## NULL
```

```r
dev.off()
```

```
## pdf
##   2
```

Meta-regression by proportion of women

```r
m.cor.reg.women <- metareg(m.cor, ~Prop_women)
```

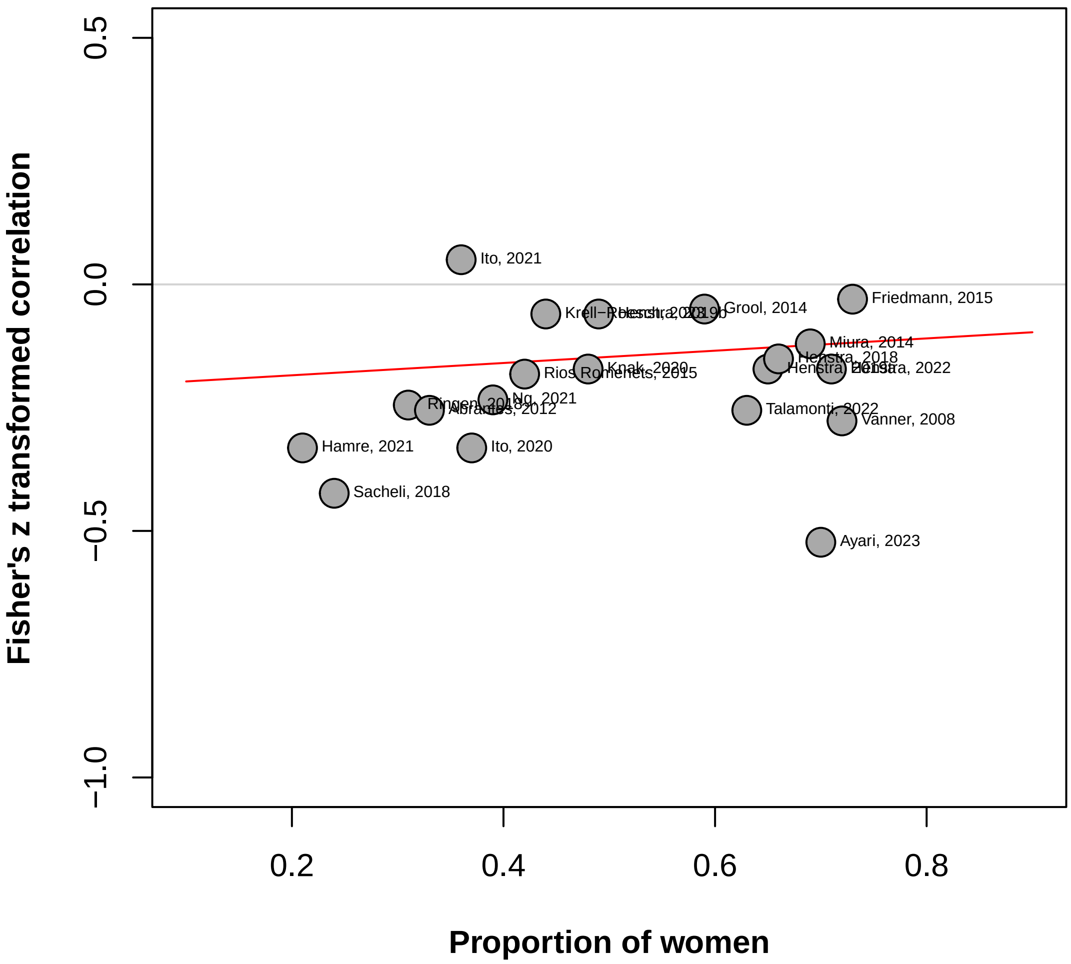
```
## Warning: 1 study with NAs omitted from model fitting.
```

```r
m.cor.reg.women
```

```
##
## Mixed-Effects Model (k = 21; tau^2 estimator: REML)
##
## tau^2 (estimated amount of residual heterogeneity):     0.0053 (SE = 0.0037)
## tau (square root of estimated tau^2 value):             0.0725
## I^2 (residual heterogeneity / unaccounted variability): 68.93%
## H^2 (unaccounted variability / sampling variability):   3.22
## R^2 (amount of heterogeneity accounted for):            0.00%
##
## Test for Residual Heterogeneity:
## QE(df = 19) = 40.6493, p-val = 0.0027
##
## Test of Moderators (coefficient 2):
## F(df1 = 1, df2 = 19) = 0.9339, p-val = 0.3460
##
## Model Results:
##
##             estimate      se     tval  df    pval    ci.lb    ci.ub
## intrcpt      -0.2093  0.0751  -2.7866  19  0.0118  -0.3665  -0.0521  *
## Prop_women    0.1247  0.1290   0.9664  19  0.3460  -0.1454   0.3948
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The proportion of women did not statistically influence the correlation values of the meta-analysis studies ($k = 21$; $p = 0.346$).

```r
Propwomen.bubble <- bubble(m.cor.reg.women,
       xlim = c(0.1, 0.9),
       ylim = c(-1, 0.5),
       xlab = 'Proportion of women',
       font.lab = 2,
       studlab = TRUE,
       cex = 2,
       cex.studlab = 0.5,
       pos.studlab = 4,
       offset = 0.5,
       col.line = 'red')
```




```r
Propwomen.bubble
```

```
## NULL
```

```r
png(file = "Bubble plot for meta-regression by proportion of women.png",
    width = 2500, height = 2500, res = 300)

Propwomen.bubble
```

```
## NULL
```

```r
dev.off()
```

```
## pdf
##   2
```

Sensitivity analysis: meta-regression by axis score

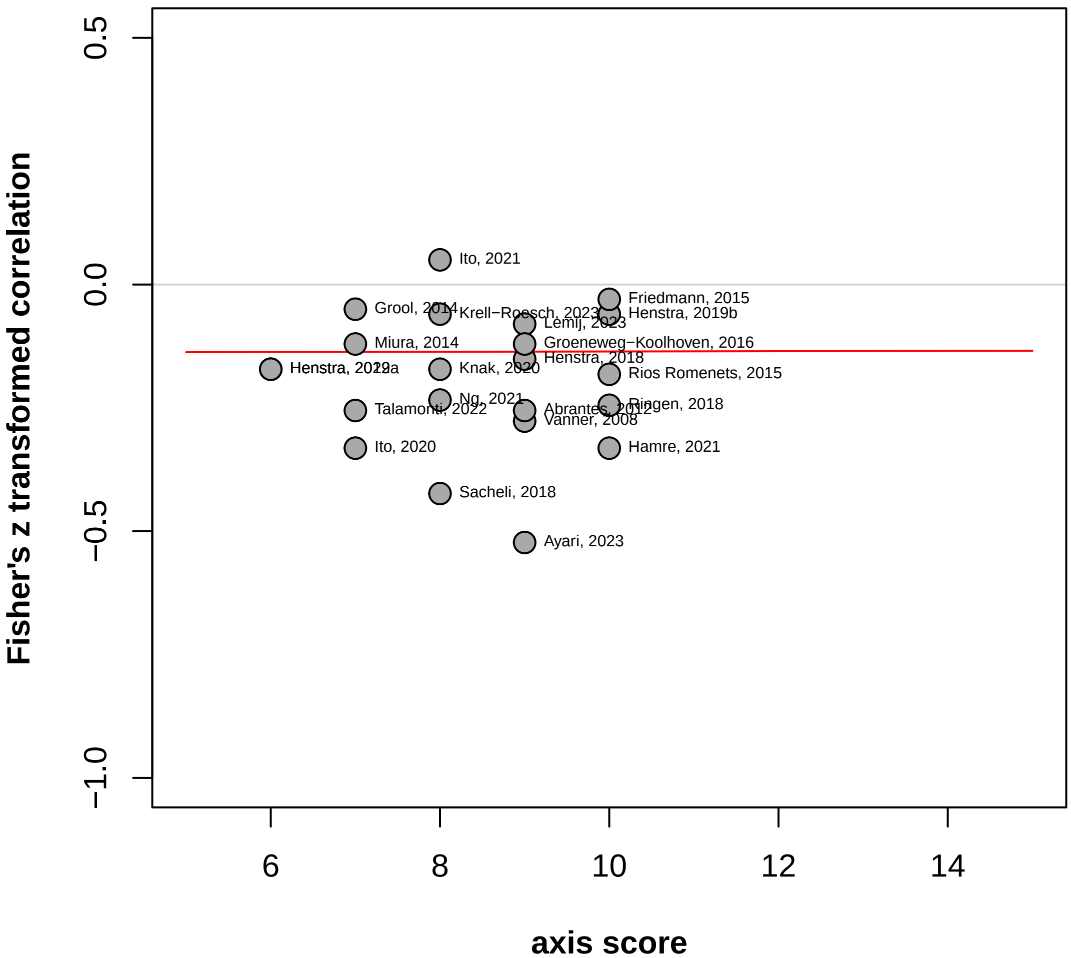
```r
m.cor.reg.axis <- metareg(m.cor, ~ Q_score)
m.cor.reg.axis
```

```
##
## Mixed-Effects Model (k = 22; tau^2 estimator: REML)
##
```

```
## tau^2 (estimated amount of residual heterogeneity):     0.0045 (SE = 0.0032)
## tau (square root of estimated tau^2 value):             0.0671
## I^2 (residual heterogeneity / unaccounted variability): 60.89%
## H^2 (unaccounted variability / sampling variability):   2.56
## R^2 (amount of heterogeneity accounted for):            0.00%
##
## Test for Residual Heterogeneity:
## QE(df = 20) = 41.1718, p-val = 0.0035
##
## Test of Moderators (coefficient 2):
## F(df1 = 1, df2 = 20) = 0.0003, p-val = 0.9862
##
## Model Results:
##
##          estimate      se     tval  df    pval    ci.lb   ci.ub
## intrcpt   -0.1386  0.1384  -1.0019  20  0.3284  -0.4273  0.1500
## Q_score    0.0003  0.0167   0.0175  20  0.9862  -0.0345  0.0351
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The meta-regression by quality score based on the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies (k = 22) showed that a study's quality did not influence correlation values (p = 0.986).

```
Axis.bubble <- bubble(m.cor.reg.axis,
                xlim = c(5, 15),
                ylim = c(-1.0, 0.5),
                xlab = 'axis score',
                studlab = TRUE,
                font.lab = 2,
                cex = 1.5,
                cex.studlab = 0.5,
                pos.studlab = 4,
                offset = 0.5,
                col.line = 'red')
```

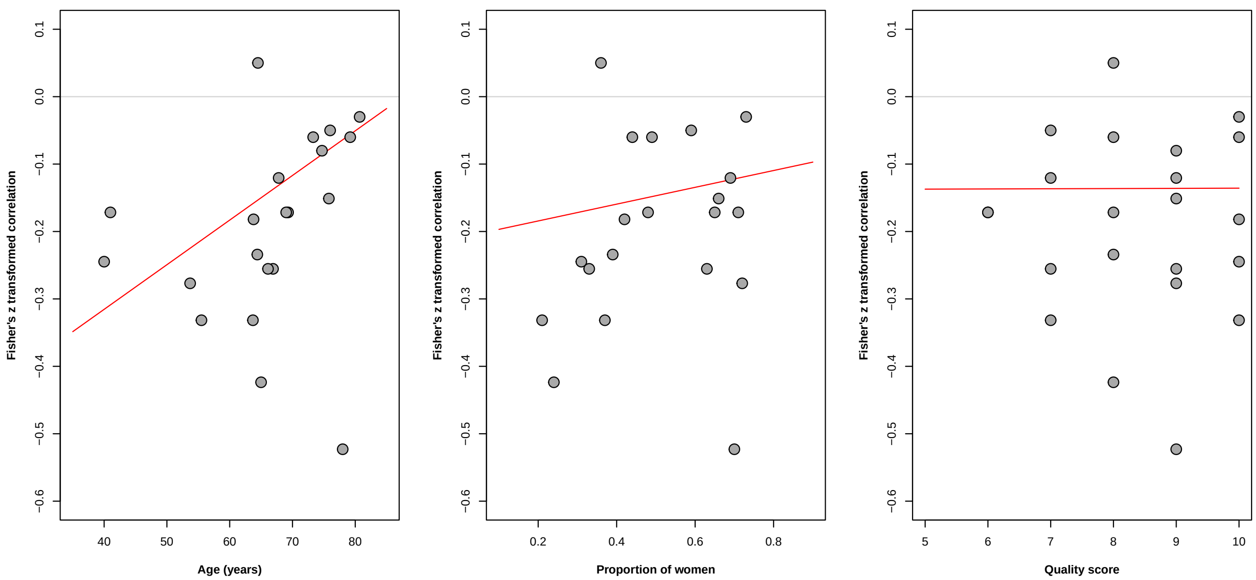



```
Axis.bubble
```

```
## NULL
```

```
parameter <- par(mfrow=c(1,3))

parameter <- bubble(m.cor.reg.age,
                    xlim = c(35, 85),
                    ylim = c(-0.6, 0.1),
                    xlab = 'Age (years)',
                    font.lab = 2,
                    studlab = F,
                    cex = 2,
                    cex.studlab = 0.5,
                    pos.studlab = 4,
                    offset = 0.5,
                    col.line = 'red')

parameter <- bubble(m.cor.reg.women,
                    xlim = c(0.1, 0.9),
                    ylim = c(-0.6, 0.1),
                    xlab = 'Proportion of women',
                    font.lab = 2,
                    studlab = F,
```

```
                    cex = 2,
                    cex.studlab = 0.5,
                    pos.studlab = 4,
                    offset = 0.5,
                    col.line = 'red')

parameter <- bubble(m.cor.reg.axis,
                   xlim = c(5, 10),
                   ylim = c(-0.6, 0.1),
                   xlab = 'Quality score',
                   studlab = F,
                   font.lab = 2,
                   cex = 2,
                   cex.studlab = 0.5,
                   pos.studlab = 4,
                   offset = 0.5,
                   col.line = 'red')
```



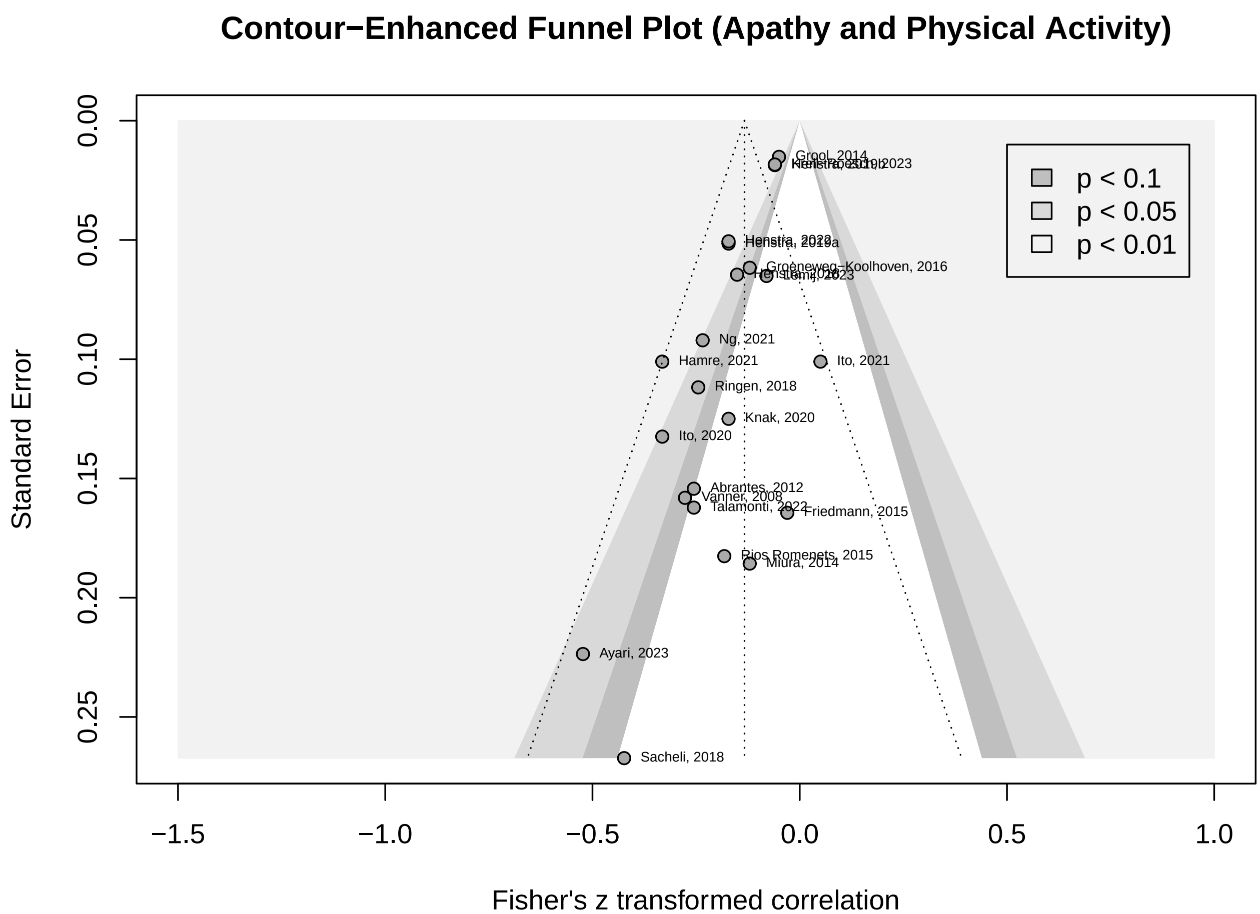
Publication bias analysis

Small-study effects

Funnel plot

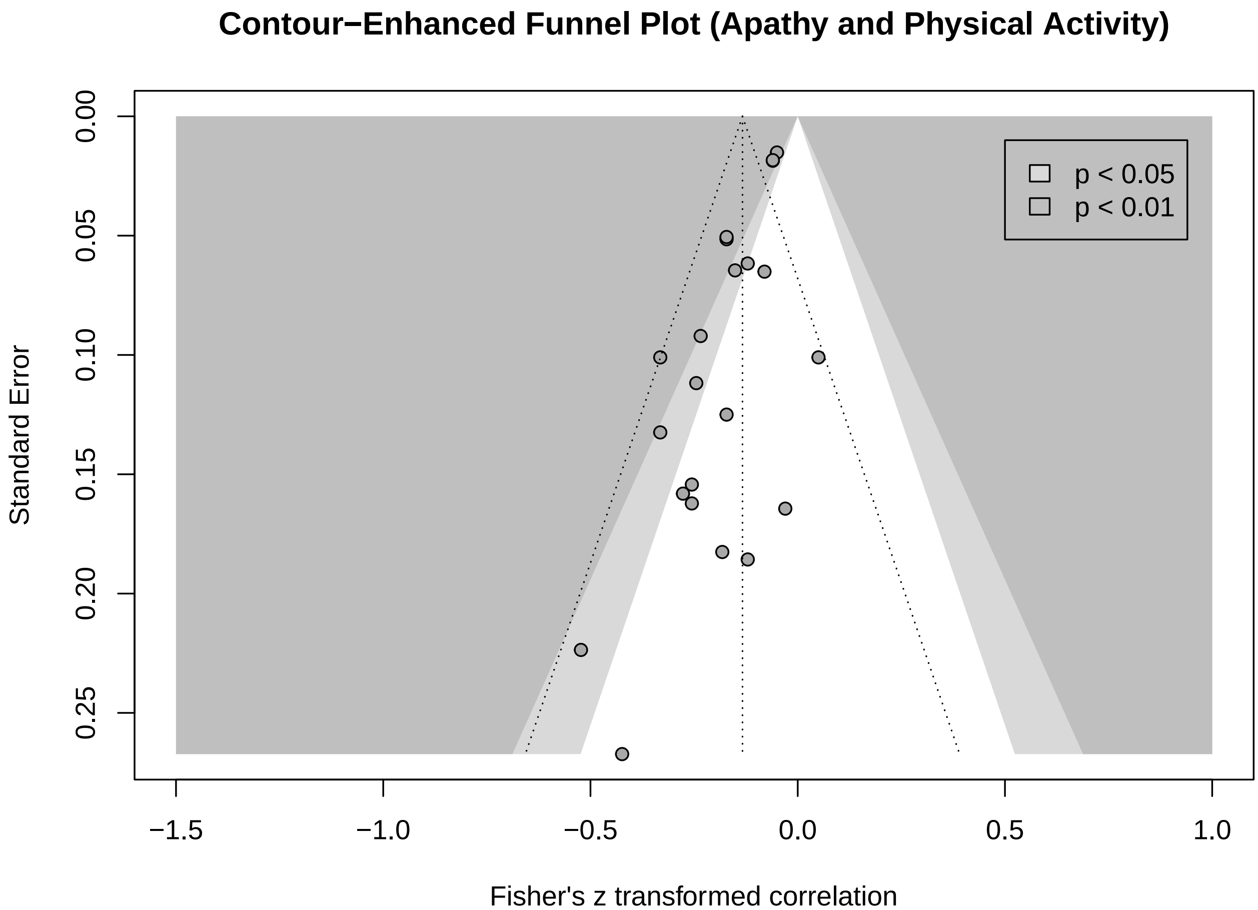
```
# Define fill colors for contour
col.contour = c("gray75", "gray85", "gray95")

# Funnel plot
funnel(m.cor,
       xlim = c(-1.5, 1),
       contour = c(0.9, 0.95, 0.99),
       col.contour = col.contour,
       studlab = TRUE,
       cex = 1,
       cex.studlab = 0.5,
```

```r
       pos.studlab = 4,
       offset = 0.5)

# legend
legend(x =0.5, y = 0.01,
       legend = c("p < 0.1", "p < 0.05", "p < 0.01"),
       fill = col.contour)

# title
title("Contour-Enhanced Funnel Plot (Apathy and Physical Activity)")
```

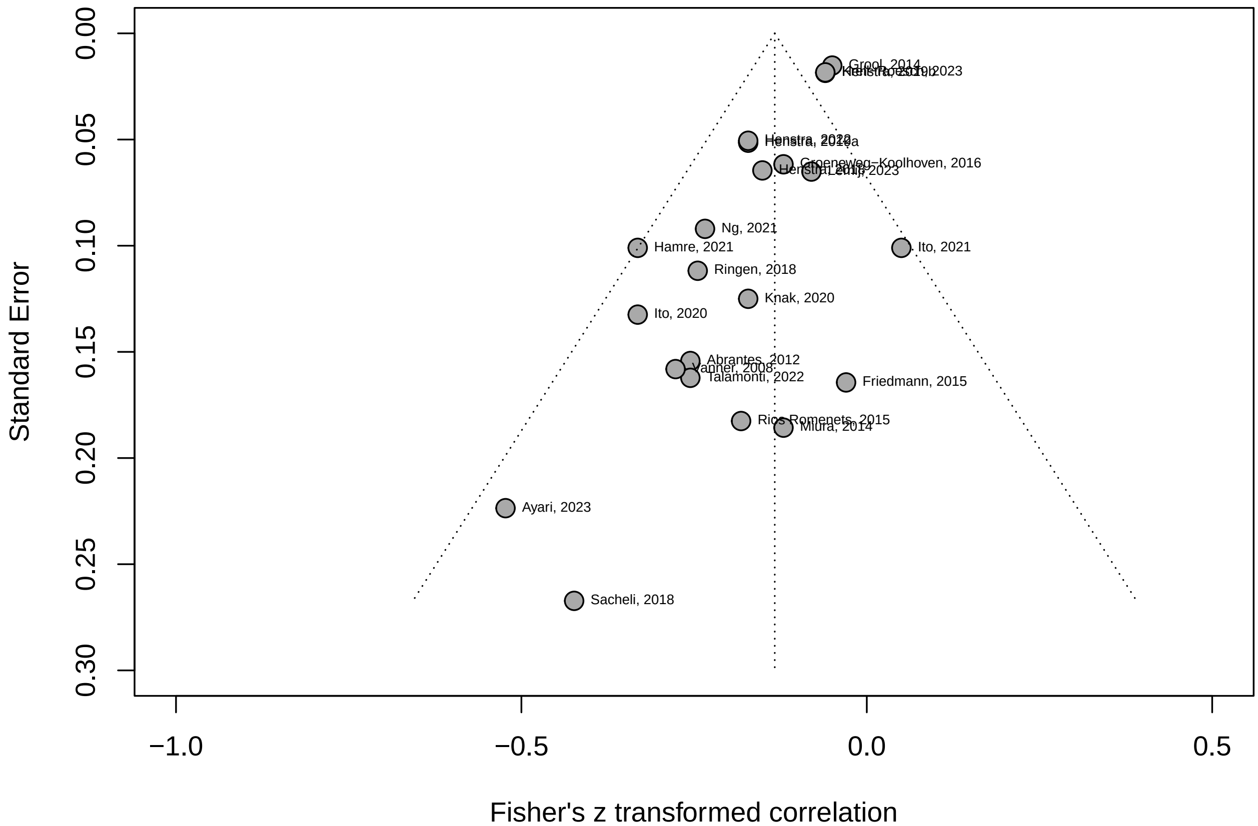



```r
# Define fill colors for contour
col.contour = c("gray85", "gray75")

# Funnel plot
funnel(m.cor,
       xlim = c(-1.5, 1),
       contour = c(0.95, 0.99),
       studlab = FALSE,
       cex = 1,
       cex.studlab = 0.5,
       pos.studlab = 4,
       offset = 0.5,
       col.contour = col.contour)
```

```r
# legend
legend(x =0.5, y = 0.01,
       legend = c("p < 0.05", "p < 0.01"),
       fill = col.contour)

# title
title("Contour-Enhanced Funnel Plot (Apathy and Physical Activity)")
```




```r
# Produce funnel plot
funnel(m.cor,
            xlim = c(-1, 0.5),
            ylim = c(0.3, 0.0),
            studlab = TRUE,
            cex = 1.5,
            cex.studlab = 0.5,
            pos.studlab = 4,
            offset = 0.5)
```




```r
png(file = "Funnel Plot.png", width = 2100, height = 1500, res = 300)

# Define fill colors for contour
col.contour = c("gray75", "gray85", "gray95")

# Funnel plot
funnel(m.cor,
       xlim = c(-1.5, 1),
       contour = c(0.9, 0.95, 0.99),
       col.contour = col.contour,
       studlab = TRUE,
       cex = 1,
       cex.studlab = 0.5,
       pos.studlab = 4,
       offset = 0.5)

# legend
legend(x =0.5, y = 0.01,
       legend = c("p < 0.1", "p < 0.05", "p < 0.01"),
       fill = col.contour)

# title
title("Contour-Enhanced Funnel Plot (Apathy and Physical Activity)")

dev.off()
```

```
## pdf
##   2
```

Egger's test

```r
metabias(m.cor, method.bias = "linreg", k.min = 9)
```

```
## Review:     Apathy and physical activity behaviour
##
## Linear regression test of funnel plot asymmetry
##
## Test result: t = -5.34, df = 20, p-value < 0.0001
##
## Sample estimates:
##     bias se.bias intercept se.intercept
##  -1.4426  0.2702   -0.0346       0.0113
##
## Details:
## - multiplicative residual heterogeneity variance (tau^2 = 0.8489)
## - predictor: standard error
## - weight:    inverse variance
## - reference: Egger et al. (1997), BMJ
```

```r
eggers.test(m.cor)
```

```
## Eggers' test of the intercept
## =============================
##
##  intercept        95% CI      t            p
##     -1.443 -1.97 - -0.91 -5.339 3.166541e-05
##
## Eggers' test indicates the presence of funnel plot asymmetry.
```

Egger's regression test showed that the data in the funnel plot was asymmetric (b = -1.44, 95% CI: -1.97 to -0.91, p = 3.1 x 10-5), which may be explained by publication bias, but also by other potential causes, such as different study procedures and between-study heterogeneity.

Limit meta-analysis

```r
limitmeta(m.cor)
```

```
## Review:     Apathy and physical activity behaviour
##
## Result of limit meta-analysis:
##
##  Random effects model     COR              95%-CI     z     pval
##     Adjusted estimate -0.0797 [-0.1366; -0.0224] -2.72   0.0065
##   Unadjusted estimate -0.1325 [-0.1765; -0.0879] -6.14 < 0.0001
##
## Quantifying heterogeneity:
## tau^2 = 0.0038; I^2 = 49.0% [16.4%; 68.9%]; G^2 = 27.9%
##
## Test of heterogeneity:
##      Q d.f.  p-value
##  41.18   21   0.0053
##
## Test of small-study effects:
##   Q-Q' d.f.  p-value
##  24.20    1 < 0.0001
```

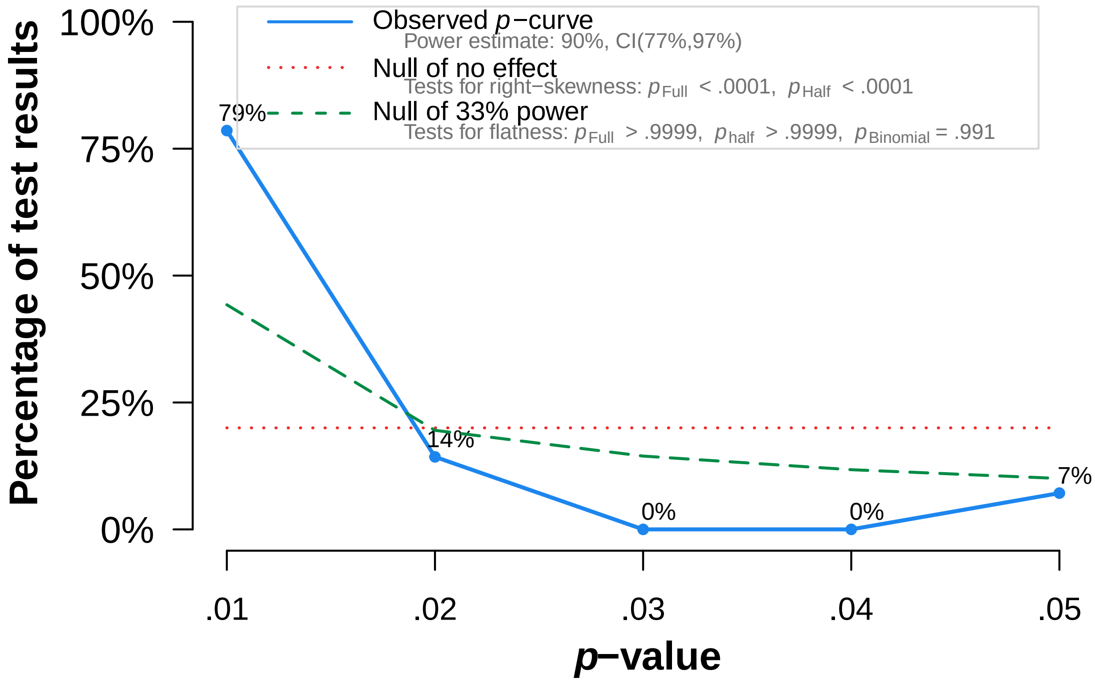
```
##
## Test of residual heterogeneity beyond small-study effects:
##     Q' d.f.  p-value
##  16.98   20   0.6544
##
## Details on adjustment method:
## - expectation (beta0)
```

The bias-corrected estimate of the true effect size, calculated using Rücker's limit meta-analysis method, showed that the correlation would remain significant if there was publication bias (r = -0.08; 95% CI: -0.14 to -0.02; p = 0.0065).

Pcurve analysis

Standard errors of the correlation values were calculated using the formula: sqrt((1 - correlation_coefficient^2) / (sample_size - 2))

```
p_curve_data = data.frame("studlab" = c(paste("Study_", 1:29, sep = "")),
                 "TE" = c(-0.27, -0.057, -0.37, -0.23, -0.25, -0.18, -0.03, -0.25,
                          -0.048, -0.12, -0.32, 0.05, -0.17, -0.08, -0.49, -0.39,
                          -0.15, 0.01, -0.11, -0.71, -0.31, -0.12, -0.15, -0.32,
                          -0.05, -0.17, -0.06, -0.17, -0.06),

                 "seTE" = c(0.150373518685809, 0.257779104402717, 0.103225750448013,
                            0.089212238675037,0.147656105804655, 0.176671738616584,
                            0.162148405058939, 0.155043418, 0.217966358,
                            0.0611010092660779, 0.095219046, 0.100378073, 0.122229293,
                            0.064748784, 0.085479417225615, 0.090293325, 0.108522387,
                            0.109758772, 0.109098165, 0.109977825, 0.170757326,
                            0.181254885, 0.063686864, 0.124402018, 0.015139517,
                            0.050685773, 0.018564909, 0.049772441, 0.018337961))

pcurve(p_curve_data)
```



Note: The observed p−curve includes 14 statistically significant (p < .05) results, of which 13 are p < .025.
There were 15 additional results entered but excluded from p−curve because they were p > .05.

```
## P-curve analysis
##  -----------------------
## - Total number of provided studies: k = 29
## - Total number of p<0.05 studies included into the analysis: k = 14 (48.28%)
## - Total number of studies with p<0.025: k = 13 (44.83%)
##
## Results
##  -----------------------
##                     pBinomial  zFull pFull  zHalf pHalf
## Right-skewness test     0.001 -7.775     0 -7.434     0
## Flatness test           0.991  4.647     1  7.099     1
## Note: p-values of 0 or 1 correspond to p<0.001 and p>0.999, respectively.
## Power Estimate: 90% (77.1%-96.5%)
##
## Evidential value
##  -----------------------
## - Evidential value present: yes
## - Evidential value absent/inadequate: no
```

The 29 studies reporting a correlation value (Pearson's r or Spearman's rho) were provided to the p-curve analysis. The observed p-curve includes 14 (48.3%) statistically significant results ($p < 0.05$), with 13 of them being $p < 0.025$ (Figure 4). The other results were excluded because they had a $p > 0.05$. The p-value of the right-skewness test was < 0.001 for both the half curve and the full curve, suggesting that evidential value was present, i.e., that the effect we estimated is not spurious; an artifact caused by selective reporting (e.g., p-hacking) in the literature.

References

- Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed.; 1988.

- Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ. 1997;315(7109):629-634. https://doi.org/10.1136/bmj.315.7109.62

- Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat Med. 2002;21(11):1539-1558. https://doi.org/10.1002/sim.1186
- Knapp G, Hartung J. Improved tests for a random effects meta-regression with a single covariate. Stat Med. 2003;22(17):2693-2710. https://doi.org/10.1002/sim.1482

- R Core Team. R: A language and environment for statistical computing [Computer software]. Version 4.3.1. Vienna, Austria: Foundation for Statistical Computing; 2023. https://www.r-project.org
- Schwarzer G. Meta: General package for meta-analysis [R package]. Version 6.5-0; 2023a. https://cran.r-project.org/web/packages/meta/meta.pdf
- Schwarzer G, Carpenter RJ, Rücker G. Metasens: Advanced statistical methods to model and adjust for bias in meta-analysis [R package]. Version 1.5-2; 2023b. https://cran.r-project.org/web/packages/metasens/metasens.pdf

- Simonsohn U, Nelson LD, Simmons JP. P-curve: A key to the file-drawer. J Exp Psychol Gen. 2014;143(2):534-547. http://doi.org/10.1037/a0033242

- Viechtbauer W. Bias and efficiency of meta-analytic variance estimators in the random-effects model. J Educ Behav Stat. 2005;30(3):261-293. https://doi.org/10.3102/10769986030003261

- Viechtbauer W. Conducting meta-analyses in R with the metafor package. J Stat Softw. 2010;36(3):1-48. https://doi.org/10.18637/jss.v036.i03

- Viechtbauer W. Metafor: Meta-analysis package for R [R package]. Version 4.2-0; 2023. https://cran.r-pro-ject.org/web/packages/metafor/metafor.pdf

- Viechtbauer, "W. (2023). Metafor: Meta-Analysis Package for R (Version 4.2-0) [R pakage]. https://cran.r-project.org/web/packages/metafor/metafor.pdf