Clinical Sports Medicine Update

The Effects of Rest on Concussion Symptom Resolution and Recovery Time

A Meta-analytic Review and Subgroup Analysis of 4329 Patients

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Background: Numerous individual studies suggest that rest may have a negative effect on outcomes following concussion.

Purpose: To perform a systematic meta-analysis of the effects of prescribed rest compared with active interventions after concussion.

Study Design: Meta-analysis; Level of evidence, 4.

Methods: A meta-analysis (using the Hedges *g*) of randomized controlled trials and cohort studies was conducted to evaluate the effects of prescribed rest on symptoms and recovery time after concussion. Subgroup analyses were performed for methodological, study, and sample characteristics. Data sources were obtained from systematic search of key terms using Ovid Medline, Embase, Cochrane Database of Systematic Reviews, APA PsycINFO, Web of Science, SPORTDiscus, and ProQuest dissertations and theses through May 28, 2021. Eligible studies were those that (1) assessed concussion or mild traumatic brain injury; (2) included symptoms or days to recovery for $\geq$2 time points; (3) included 2 groups with 1 group assigned to rest; and (4) were written in the English language.

Results: In total, 19 studies involving 4239 participants met criteria. Prescribed rest had a significant negative effect on symptoms (k = 15; g = –0.27; SE = 0.11; 95% CI, –0.48 to –0.05; P = .04) but not on recovery time (k = 8; g = –0.16; SE = 0.21; 95% CI, –0.57 to 0.26; P = .03). Subgroup analyses suggested that studies with shorter duration (<28 days) (g = –0.46; k = 5), studies involving youth (g = –0.33; k = 12), and studies focused on sport-related concussion (g = –0.38; k = 8) reported higher effect sizes.

Conclusion: The findings support a small negative effect for prescribed rest on symptoms after concussion. Younger age and sport-related mechanisms of injury were associated with a greater negative effect size. However, the lack of support for an effect for recovery time and the relatively small overall numbers of eligible studies highlight ongoing concerns regarding the quantity and rigor of clinical trials in concussion.

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Keywords: concussion; mild traumatic brain injury; prescribed rest; active intervention; meta-analysis

The Centers for Disease Control and Prevention estimates there were 2 million emergency department visits for a sport and recreation–related concussion among children and adolescents <18 years between 2010 and 2016.[54] A majority (up to 65%) of recreation-related injuries are not seen in health care settings.[8] However, increasing evidence shows that early physical activity, which can be guided by health care providers, not only is safe but also may be more effective than rest-based strategies in reducing symptoms and enhancing recovery.[43,60] Despite these emerging findings, current consensus promotes initial (<48 hours) rest and symptom-limited physical activity after concussion,[47] perhaps because most of these findings were reported after the consensus meeting. In 2018, the

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American Academy of Pediatrics (AAP) promoted a reduction of physical and cognitive activity immediately after a concussion, cautioned against complete inactivity, and supported light physical exertion such as brisk walking.[28] In 2019, the American Medical Society for Sports Medicine (AMSSM) supported 24 to 48 hours of rest followed by exercise below symptom-exacerbation thresholds.[29] Both AAP and AMSSM recommendations endorse only subsymptom threshold exercise after a concussion, despite emerging evidence that some provocation of symptoms after concussion is safe.[56]

During the past several years, researchers have reported the results from several systematic and meta-analytic reviews of the outcomes of active treatments on concussion. In a recent meta-analysis of 23 studies of active rehabilitation for concussion, Carter et al[10] reported a large positive effect for physical activity on symptom improvement after concussion (g = 1.03). The effect in this the Carter et al study for subthreshold aerobic activity was even larger (g = 1.71). In a meta-analysis of data from 8 studies of subthreshold aerobic exercise and cervical, vestibular, and oculomotor therapies, subthreshold aerobic exercise was associated with a reduction in concussion symptoms but not time to recovery.[52] These researchers also reported that individualized, multimodal interventions were effective for reducing recovery time in patients with persistent postconcussion symptoms. However, the analyses by Reid et al[52] included only a small number of studies, calling into question the validity of the reported subgroup analyses. In a more focused, smaller meta-analysis, Shen et al[55] reported that among randomized controlled trials (RCTs) only, aerobic exercise reduced symptom scores and accelerated recovery but did not improve neurocognitive test performance. Langevin and colleagues[41] conducted a meta-analysis of RCTs involving adolescents and symptom-limited aerobic exercise and reported that across 7 studies, aerobic exercise had a positive, although low effect on reported symptoms. Of note, these researchers reported a high risk of bias in 3 of the 7 included studies. Collectively, these studies highlight several key trends in the concussion intervention literature including a dearth of high-quality research designs, small individual study sample sizes, inconsistent outcome data, and lack of clarity regarding the characteristics of intervention groups. In addition, absent from these studies is an emphasis on the potential deleterious effects of rest, with a focus instead on the positive effects of active interventions on symptoms and recovery time.

Increasing evidence challenges the effectiveness of prescribed rest and even suggests that rest beyond the first 24 to 48 hours may be detrimental to patients after concussion.[9,43,60] However, recent systematic and meta-analytic reviews of the empirical literature have focused more on the positive effects of exercise and other active interventions than on the negative effect of rest per se.[41,48,55] Therefore, the primary purpose of this study was to use a meta-analytic approach to evaluate the negative effect of rest compared with physical activity and other active interventions in patients after concussion across multiple studies. We hypothesized that the results of the meta-analysis would support a negative effect (ie, increased symptoms and longer recovery time) across studies for prescribed rest compared with prescribed physical activity in patients after concussion. A secondary purpose of this study was to evaluate the degree to which methodological (research design, study outcome, time since injury, study duration), sample (age, injury context), and study (publication status) characteristics moderate the effect of rest versus physical activity recommendations on outcomes.

METHODS

Database Keywords, Search Strategy, Study Identification

Ovid Medline, Embase (embase.com), Cochrane Database of Systematic Reviews (via Wiley, no trials), APA PsycINFO (Ovid), Web of Science (Clarivate Analytics), SPORTDiscus (EBSCO), and ProQuest dissertations and theses (ProQuest) were searched to identify relevant studies for review through May 28, 2021. Search strategies were developed in collaboration with a health sciences librarian using a combination of keywords and database-specific subject headings. Key concepts included brain concussion (concussion, mild traumatic brain injury, or postconcussion syndrome) and rest (stretching, no activity, no exercise, no training). An additional search strategy was developed to identify studies using placebo as a comparison in an exercise intervention. Search results were limited to

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those published after 1980. No other limits were used. The full Medline search strategy is included in the Appendix (available in the online version of this article). Once results were exported from all databases, duplicates were removed using the Amsterdam Efficient Deduplication method[50] and the Bramer method.[7] Literature search findings were recorded and screened by title and abstract to determine inclusion using DistillerSR.[18] If the title and abstract were insufficient, the article was retrieved to complete the inclusion review. The study was prospectively registered on PROSPERO on June 14, 2021 (ID No. CRD420 21253060). The University of Pittsburgh Institutional Review Board does not require approval to conduct a meta-analysis.

Inclusion and Exclusion Criteria

The following inclusion criteria were used: (1) the study assessed concussion or mild traumatic brain injury; (2) the study included quantitative descriptive statistics for symptoms or days to recovery to allow estimation of an effect size for ≥ 2 time points; (3) 2 groups were investigated with 1 group assigned to rest; (4) the article was written in the English language and was published between January 1, 1980, and May 28, 2021. A standardized email was sent to the corresponding author requesting additional information when a study contained insufficient information or data. The exclusion criteria were as follows: (1) no full-text version of the manuscript was available; (2) no response was received from the study author after 3 attempts to contact them for additional study data or the author could not be contacted; (3) the study did not report original data regarding concussion symptoms or number of days to recovery; (4) the study was an abstract of preliminary findings or a secondary analysis of data already included in the present meta-analysis.

Definition of Rest

Due to heterogeneity in the definition of *rest* throughout the literature, rest was operationally defined in the present study to include cognitive rest, physical rest, stretching only, or standard of care (ie, a period of rest until asymptomatic before a return-to-play protocol was initiated).

Coding and Data Extraction

Coding was standardized through an electronic spreadsheet. Relevant information from the articles was extracted regarding methodological, participant, and study characteristics. Methodological characteristics included study design (experimental/quasi-experimental or cohort), outcomes measured (time to recovery in days or reported symptom severity), and symptom reporting tool (Post-Concussion Symptom Scale [PCSS],[12] Post-Concussion Symptom Inventory [PCSI],[51] Sport Concussion Assessment Tool–5 [SCAT5],[21] Health and Behavior Inventory [HBI],[49] or Rivermead Post-Concussion Questionnaire [RPQ]).[38] Participant characteristics included days from injury (<14 days or $\geq$14 days), duration of intervention or observation (<28 days or $\geq$28 days), number of participants per group, age, and sport-related or non–sport related concussion. Study characteristics included published or unpublished.

Independent Assessment of Bias

Four independent reviewers (S.R.E., J.P., L.M., A.T.) coded and rated studies according to their characteristics using the Risk of Bias Version 2.0 (Cochrane Methods) tool. After all studies meeting inclusion criteria had been coded, the independent assessments were compared for agreement. Any disagreement was analyzed to determine the type of error and subsequently was classified as either factual disagreement (transcription errors) or interpretative error (vague or imprecise information). One of the 4 researchers on the authorship team (S.R.E.) who coded the study characteristics reviewed interpretative disagreements, and the decision was based upon a simple majority.

Data Analysis

Outlier and Publication Bias. An outlier was defined as any study having a large ($\geq \pm 1.96$) residual value that might influence the summary effect. If an outlier was present, a sensitivity analysis was performed using a "1-study-removed" technique in the Comprehensive Meta-Analysis software. The 1-study-removed procedure recalculates the meta-analytic statistics to determine the overall results if the study was removed. The decision to include a study was based on results remaining unchanged (marginal influence on the effect size and associated P value) and within the 95% CI. Publication bias was considered to influence published or unpublished studies not identified or included during the literature search or screening process. Three procedures were used to screen for publication bias that included review of the funnel plot in combination with a "trim and fill" method, Begg and Mazumdar rank correlation, and the Egger regression intercept.[1,19,20,22]

Model, Effect Size, Interpretation. All analyses were performed using Comprehensive Meta-Analysis Version 3 software.[5] A random-effects model was selected to interpret results, because both between-study variance and sampling error were expected.[4,31] The Hedges g was selected as the effect size index used to correct for small sample sizes ($k < 20$).[3,30] The rationale for using the Hedges g was also based on the use of additional analyses (outcomes and subgroups) that contained fewer than the recommended number of studies or inconsistency in reporting results. Smaller sample sizes are likely to create an imprecise estimate of effect, and a common method for handling this problem is to use a pooled estimate of variance to conduct analyses.[39] The unit of analysis was considered to be the study; when multiple time points were provided within a study, scores across time were averaged to yield a summary effect. Interpretation of statistical information is based on the Cohen criteria for evaluating small ($\geq$0.20), medium ($\geq$0.50), and large

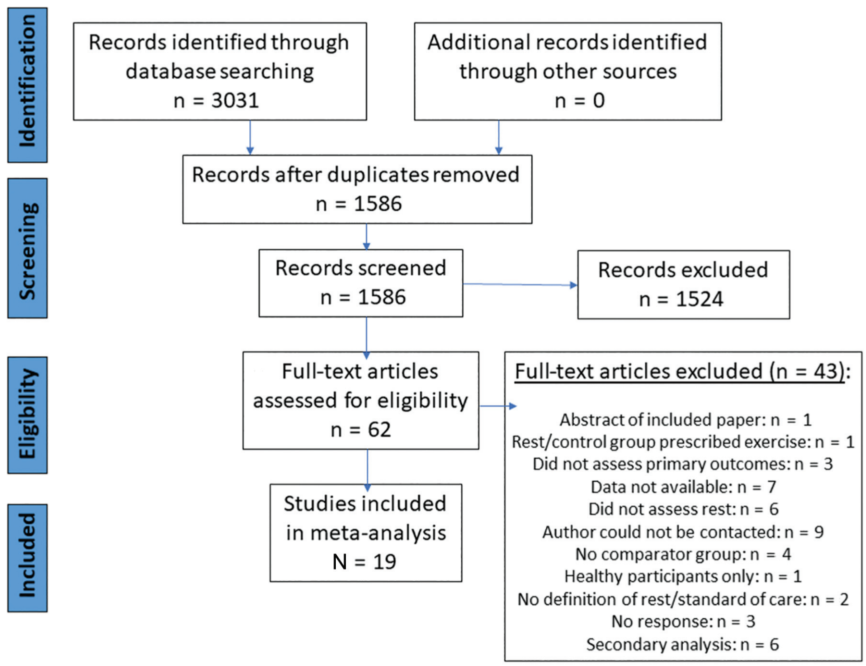

Figure 1. Screening and exclusion diagram.

($\geq$0.80) effects using the d metric.[14,15] Negative effect sizes were interpreted to support exercise conditions, whereas positive effect sizes represented more favorable results for rest conditions. To provide a comprehensive review and direction for future research, data for outcomes and subgroup analyses with small sample sizes are reported but not discussed given that a small sample prevents confident interpretation.

Outcome Analyses. There were 2 outcomes of interest: number of days to recovery and the number and intensity (ie, severity) of symptoms experienced by individuals diagnosed with a concussion. Four statistics were used to evaluate heterogeneity and provide a comprehensive approach to interpreting results. The prediction interval quantified how much studies varied, the Q_{Total} (Q_T) value based on chi-square (χ^2) distribution reports whether studies shared the same effect size, the tau-square (τ^2) value provided the variance of true effects between studies, and the I-square (I^2) value estimated the proportion of the variance between observed and true effects. Significant Q_T statistics were then categorized as $Q_{Between}$ (Q_B) and Q_{Within} (Q_W) values, and significant Q_B values ($P < .05$) required statistical techniques to determine subgroup differences.[6] Small subgroup sample sizes ($k \leq 10$) may influence the precision of τ^2; therefore, a pooled estimate of variance was used for all calculations.[2] The I^2 statistic reflected the overlap of confidence intervals and can be interpreted as a low (25%), moderate (50%), or high (75%) percentage of the total variance attributed to covariates.[32] Negative effect sizes were interpreted as control (or exercise) conditions or groups having a favorable outcome, and positive effect sizes were indicative of intervention or treatment (rest) conditions producing stronger results with respect to concussion recovery.

Subgroup Analyses. Coding forms were developed to extract article information in 3 categories: (1) methodological characteristics, (2) sample characteristics, and (3) study characteristics. Methodological characteristics included study design (cohort, experimental), symptom outcome measures (HBI, PCSI, PCSS, RPQ, and SCAT5), time since injury (<14 days, $\geq$14 days), and study duration, (<28 days, $\geq$28 days). Sample characteristics included age (youth, adult) and injury context (sport, mixed). Study characteristics included study status (published, unpublished). Subgroup analyses were then performed within each category in an attempt to identify potential moderators of the overall effect of the intervention or clinical management approach on concussion recovery.

RESULTS

Overview of the Sample

A total of 19 studies enrolling 4239 participants met inclusion criteria: 15 studies reported symptom number and/or intensity outcomes, and 8 studies reported symptom duration (in days). Figure 1 provides the results from the search strategy and article screening process, and Table 1 provides the coding characteristics collected from each study to perform the subgroup analyses. The interrater reliability (kappa) coefficient met review standards ($\kappa > 0.9$) with a total of 2 disagreements that included 1 factual error and 1 interpretative difference. Factual errors were corrected, and interpretative errors were analyzed and reflected the majority decision.

TABLE 1
Coding for Studies Meeting Inclusion Criteria[a]

	Methodological Characteristics				Sample Characteristics				Study Characteristics
Lead Author (Year)	Research Design	Measured Outcomes	Days Since Injury	Days of Rest	N	Concussion History	Participant Age	Injury Context	Publication Status
Buckley[9] (2016)	C	RD	<14	<28	50	NR	A	S	P
Chan[11] (2018)	E	PCSS	≥14	≥28	19	NR	Y	S	P
Chrisman[13] (2019)	E	HBI	≥14	≥28	30	R	Y	S	P
Congeni[16] (2022)	E	SCAT5	<14	<28	55	NR	Y	S	P
Coslick[17] (2020)	C	RD	≥14	<28	178	R	Y	M	P
Gauvin-Lepage[24] (2020)	E	PCSI	≥14	≥28	49	R	Y	M	P
Gibson[25] (2013)	C	RD	≥14	NR	177	R	MS	M	P
Grool[27] (2016)	C	PCSI	NR	<28	2405	R	Y	NR	P
Howell[35] (2016)	C	PCSS	<14	NR	218	R	MS	S	P
Howell[33] (2020)	C	PCSS	<14	NR	72	R	A	M	P
Howell[34] (2021)	C	PCSI	<14	≥28	37	R	MS	M	P
Kurowski[40] (2017)	E	PCSI	≥14	≥28	30	NR	Y	M	P
Leddy[42] (2019)	E	PCSS	<14	<28	103	R	Y	NR	P
Root[53] (2019)	C	PCSI	<14	≥28	165	R	Y	M	P
Soliman[57] (2019)	E	PCSS	<14	<28	20	NR	A	S	U
Stumph[58] (2020)	C	PCSS	<14	NR	194	R	Y	S	P
Thomas[60] (2015)	E	PCSS	<14	<28	93	R	Y	M	P
Varner[64] (2020)	E	RPQ	NR	≥28	141	R	A	M	P
Worts[66] (2019)	C	RD	<14	NR	177	R	Y	NR	U

[a]A, adult ≥18 years of age; C, cohort; E, experimental; HBI, Health and Behavior Inventory; M, mixed injuries including sport, violence, and falls; MS, mixed sample with adults and youth; NR, not reported; P, published; PCSI, Post-Concussion Symptom Inventory; PCSS, Post-Concussion Symptom Scale; R, reported; RD, recovery days; RPQ, Rivermead Post-Concussion Symptoms Questionnaire; S, sport-related injury; SCAT5, Sport Concussion Assessment Tool; U, unpublished; Y, youth <18 years of age.

Random-Effects Model

Given the small number of studies in the analysis, a Knapp-Hartung adjustment was performed to provide a more accurate calculation for confidence intervals and standard error.[2] The summary treatment effect for studies meeting inclusion criteria produced a small, significant effect (k = 15; g = –0.27; SE = 0.11; 95% CI, –0.48 to –0.05; P = .04) for the symptoms outcome that favored exercise conditions that is approximately 0.27 SD greater than rest or treatment conditions. Recovery as an outcome did not produce a significant effect (k = 8; g = –0.16; SE = 0.21; 95% CI, –0.57 to 0.26; P = .03), and further analysis was not performed as a result of these findings. Table 2 and Figures 2 and 3 display the relevant statistics and forest plots for symptom recovery from concussion.

Outliers and Publication Bias

One study was identified as an outlier[16] with a residual value of 2.03. Therefore, a sensitivity analysis was performed to determine whether to include the study. Results from the 1-study-removed (sensitivity) analysis retained the outlier, as the small increase in effect size (+ 0.05) resulting from the outlying study would not change interpretation of results. Publication bias was determined through review of the funnel plot, trim and fill procedure, Begg and Mazumdar rank-order correlation, and Egger regression intercept. The trim and fill procedure did not add studies to the right of the plot, and the values of the point estimate and confidence intervals remained unchanged. The Kendall τ was not statistically significant (Kendall τ = 0.05; P = .84), indicating that the mean effect was similar between larger and smaller studies. Egger regression analysis was also not significant (intercept = 1.56; P = .09), providing additional confirmation that the mean effect was similar between small and large studies. Based on these combined findings, publication bias was unlikely.

Outcome Analysis

As previously indicated, concussion symptoms were the only outcome that provided a relatively accurate estimate for a summary effect. Therefore, the subgroup analyses were limited to the 15 studies that included symptoms as an outcome (see Table 1). The meta-analysis literature suggests that for studies or analyses with smaller sample sizes (k < 10), estimates of effect are unstable and should not be reported.[6] Using these recommendations, we elected to report only on the symptoms outcome. Initial results favored exercise conditions (k = 15; g = –0.27); however, review of the prediction interval for symptoms suggested that the true effect size for all comparable populations provided an interval between –1.04 and 0.51. These results indicate that the different populations responded favorably to both exercise (control) and rest (treatment) conditions.

TABLE 2
Random-Effects Model Results for Outcomes[a]

	Effect Size Statistics					Null Test	Heterogeneity Statistics		
	k	g	SE	s^2	95% CI	Z	Q	τ^2	I^2
Outcomes									
Recovery (days)	8	–0.16	0.21	0.04	–0.57, 0.26	–1.07	56.91[b]	0.29	87.70
Symptoms	15	–0.27	0.11	0.08	–0.48, –0.05	–2.43[b]	76.76[b]	0.12	81.65

[a]The total Q-value was used to determine heterogeneity. g, Hedges g effect size; I^2, total variance explained by moderator; k, number of effect sizes; s^2, variance; τ^2, between-study variance in random-effects model; Z, test of null hypothesis.
[b]$P < .05$.

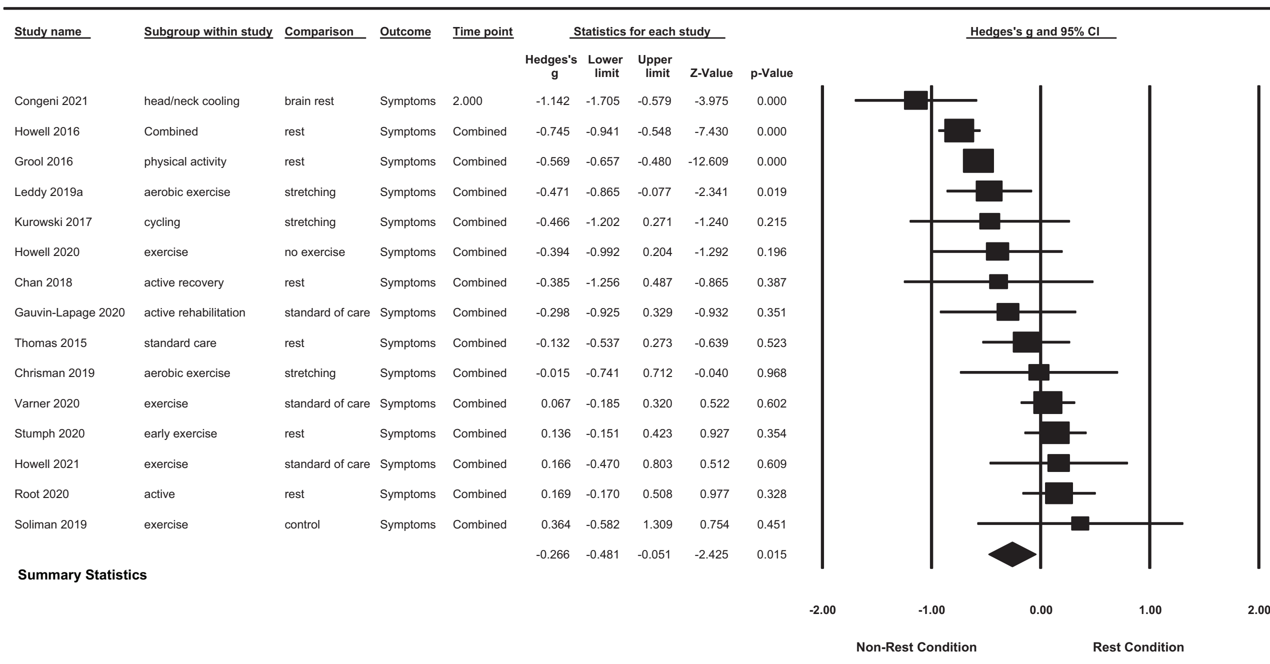

Figure 2. Forest plot for studies reporting concussion symptoms.

Subgroup Analysis

Subgroup analyses were performed based on the combination of heterogeneity statistics (Q_T = 76.30; $P < .001$; τ^2 = 0.12; I^2 = 81.76) to explain study variability. Among methodological characteristics, studies that used the SCAT5 symptom measure (g = –1.14; k = 1) and were shorter in duration (<28 days) (g = –0.46; k = 5) reported higher effect sizes. Regarding the sample characteristics, studies involving youth (g = –0.33; k = 12) and those focused on sport-related concussion (g = –0.38; k = 8) reported higher effect sizes. Finally, published studies (g = –0.29; k = 14) reported greater effect sizes. It is important to note that not all of the subgrouping variables had a critical number ($k \geq 10$) of studies to interpret the analyses (see Table 3). As such, the discussion and conclusions provided below are speculative and offer plausible explanations as well as recommendations for future study.

DISCUSSION

To our knowledge, the current study is the first meta-analysis to evaluate the negative effects of prescribed rest after concussion. The findings provide partial support to our hypothesis that there would be a significant negative effect size in clinical outcomes for patients who were prescribed prolonged rest after concussion compared with those prescribed physical activity and/or other interventions. However, this finding was supported only for symptom severity and not for recovery time. It is possible that rest affects only symptoms but not recovery time with regard to concussion recovery or that the large heterogeneity in concussion presentation confounds the effects of rest on recovery time (ie, subpopulations or concussion types respond differently to rest). However, this disparity in the effect for recovery time is somewhat expected, as recovery time is not consistently defined in the literature, resulting

Study name	Subgroup within study	Comparison	Outcome	Time point	Hedges's g	Lower limit	Upper limit	Z-Value	p-Value
Coslick 2020	moderate/heavy exercise	no/low exercise	Recovery days	2.000	-0.705	-1.073	-0.337	-3.755	0.000
Worts 2019	aerobic exercise	rest	Recovery days	2.000	-0.625	-0.968	-0.282	-3.572	0.000
Howell 2020	exercise	no exercise	Recovery days	2.000	-0.392	-0.989	0.206	-1.285	0.199
Leddy 2019a	aerobic exercise	stretching	Recovery days	2.000	-0.368	-0.755	0.018	-1.867	0.062
Soliman 2019	exercise	control	Recovery days	2.000	-0.331	-1.252	0.591	-0.703	0.482
Leddy 2019a	aerobic exercise	rest	Recovery days	2.000	-0.137	-0.521	0.247	-0.698	0.485
Stumph 2020	early exercise	rest	Recovery days	2.000	0.064	-0.221	0.350	0.443	0.658
Buckley 2016	no rest	rest	Recovery days	1.000	0.076	-0.470	0.622	0.272	0.785
Gibson 2013	no cognitive rest	cognitive rest	Recovery days	2.000	0.812	0.506	1.118	5.209	0.000
Summary Statistics					-0.165	-0.530	0.199	-0.889	0.374

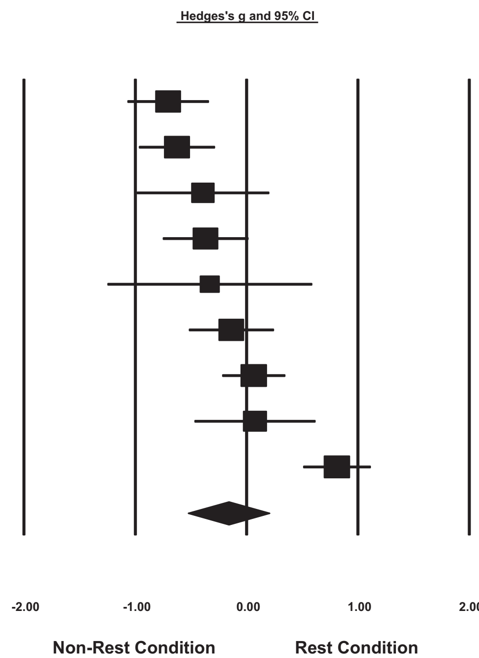

Figure 3. Forest plot for studies reporting concussion recovery in days.

in considerable variability across studies. Also, the reported effect size in this study for prescribed rest on symptoms was small (Hedges g = –0.27) per the Cohen criteria.[14] This small effect size may also be due in part to the quality and variability of studies that met study inclusion and exclusion criteria. Further, concussion often has confounding comorbidities (eg, cervical strain), and the lack of diagnostic consensus leads to variability of concussion diagnoses; it is likely that such confounding significantly affects results when aggregating studies. In addition, a majority of the studies included in the current analysis did not account for compliance with assigned interventions. As such, noncompliant patients were potentially included in both prescribed rest and the comparison intervention groups. Being noncompliant in prescribed active interventions such as exercise or vestibular therapy could lessen the positive effect associated with these interventions.[23,43] Similarly, being noncompliant with prescribed rest, such as engaging in exercise or using smart phone–based apps, may have balanced out any potential negative effects of prescribed rest.

Previous meta-analytic reviews of concussion treatment have focused on detecting benefit from active rehabilitation.[10,41,52,55] By focusing on the potential negative effects of rest beyond 24 to 48 hours after injury, we may highlight the potential detriments of this common management recommendation. Rest has increasingly been associated with worse outcomes after concussion in individual studies.[9,59,60] Although it is possible that being prescribed rest reduces a patient's exposure to the benefits of exercise or social interaction, it is also possible that rest is associated with other negative postinjury behaviors. In fact, concurrent negative behaviors (eg, reduced school attendance, sleep disruption, physical deconditioning, reduced screentime) with prescribed rest may be the cumulative driver of negative postinjury outcomes.[60] For example, a recent RCT demonstrated that increased screentime was associated with worse PCSS scores after injury and prolonged recovery.[44] It is possible that patients in the rest groups had more exposure to screentime and therefore worse outcomes. Rest may cause harm by limiting psychosocial adaptation[37] and not allowing patients to acclimate to dynamic challenges of life after injury.[63] Indeed, research on athletes with concussion compared with those with musculoskeletal injuries has suggested emotional difficulty after concussion, and rest could exacerbate this adverse effect after concussion.[36,46,61] Rest may perpetuate patients' negative perceptions of their illness.[62] Patients demonstrating a maladaptive belief that their injury is more serious are more likely to have a severe and prolonged recovery.[65]

The current findings supported several potential factors that may moderate the overall negative effect for prescribed rest. Specifically, children and adolescents experienced greater negative effects associated with prescribed rest than did adults. This finding is intuitive, in that prescribed rest and activity restrictions likely disrupt academic, social, communication/technology, and other functioning among children and adolescents more significantly than for adults.[62] The findings also indicated that patients with a sport-related concussion experienced more significant negative effects from prescribed rest than those with non–sport related injury mechanisms. Patients injured in sport may experience greater

TABLE 3
Subgroup Analyses for Symptom Outcomes[a]

	Effect Size Statistics					Null Test	Heterogeneity Statistics		
	k	g	SE	s^2	95% CI	Z	Q	τ^2	I^2
Random effects model[b]	15	–0.27	0.11	0.01	–0.49, –0.05	–2.44[c]	76.30[c]	0.12	81.65
Methodological Characteristics[d]									
Research design							0.04[d]		
Cohort	6	–0.24	0.16	0.03	–0.56, 0.07	–1.52	46.42[c]	0.12	81.65
Experimental	9	–0.29	0.15	0.02	–0.59, 0.01	–1.87	19.36[c]	0.12	81.65
Symptom measure							4.12[d]		
HBI	1	–0.02	0.54	0.30	–1.08, 1.05	–0.03	0.00	0.12	81.65
PCSI	5	–0.21	0.21	0.04	–0.62, 0.20	–1.00	21.89[c]	0.12	81.65
PCSS	7	–0.27	0.18	0.03	–0.63, 0.08	–1.52	29.51[c]	0.12	81.65
RPQ	1	0.07	0.42	0.17	–0.75, 0.89	0.16	0.00	0.12	81.65
SCAT5	1	–1.14	0.49	0.24	–2.10, –0.18	–2.33[c]	0.00	0.12	81.65
Time since injury							0.10[d]		
<14 days	9	–0.25	0.16	0.02	–0.57, 0.06	–1.56	49.33[c]	0.12	81.65
≥14 days	4	–0.29	0.28	0.08	–0.84, 0.27	–1.02	0.82	0.12	81.65
Not reported	2	–0.26	0.31	0.09	–0.86, 0.34	–0.86	21.71[c]	0.12	81.65
Study duration							3.84[d]		
<28 days	5	–0.46	0.18	0.03	–0.81, –0.12	–2.63[c]	12.24[c]	0.12	81.65
≥28 days	7	–0.05	0.16	0.03	–0.38, 0.26	–0.34	4.58	0.12	81.65
Not reported	3	–0.34	0.21	0.05	–0.76, 0.03	–1.62	24.66[c]	0.12	81.65
Sample Characteristics[d]									
Age							2.61[d]		
Adult	3	–0.01	0.16	0.03	–0.32, 0.31	–0.37	1.12	0.12	81.65
Youth	12	–0.33	0.12	0.01	–0.56, –0.10	–2.77[c]	7.18[c]	0.12	81.65
Injury context							0.81[d]		
Sport	8	–0.38	0.19	0.04	–0.74, –0.01	–2.04[c]	34.52[c]	0.12	81.65
Mixed	7	–0.15	0.17	0.03	–0.48, 0.18	–0.90	41.61	0.12	81.65
Study Characteristics[d]									
Status							1.18[d]		
Published	14	–0.29	0.11	0.01	–0.51, –0.07	–2.61[c]	73.94[c]	0.12	81.65
Unpublished	1	–0.36	0.59	0.35	–0.79, 1.52	0.61	0.00	0.12	81.65

[a]g, effect size (Hedges g); HBI, Health and Behavior Inventory; I^2, total variance explained by moderator; k, number of effect sizes; PCSI, Post-Concussion Symptom Inventory; PCSS, Post-Concussion Symptom Scale; RPQ, Rivermead Post-Concussion Symptoms Questionnaire; s^2, variance; SCAT5, Sport Concussion Assessment Tool; τ^2, between-study variance in random-effects model; Z, test of null hypothesis.
[b]Total Q-value used to determine heterogeneity.
[c]$P < .05$.
[d]Between Q-value used to determine significance ($\alpha < .05$). Both τ^2 and I^2 are assumed to be the same, as values are computed within subgroups and then pooled across subgroups.

frustrations and perceived negative effects (ie, increased symptoms) from the restrictions in activity and engagement in their sport associated with prescribed rest than nonsport patients.[62] In addition, non–sport related concussions involving motor vehicle collisions, falls, assaults, and other mechanisms may be more severe than concussions from sport[26] and involve individuals with lower premorbid fitness levels and overall health. Athletes may be physiologically distinct from nonathletes before injury with regard to cardiovascular fitness and conditioning perspective, which may influence the effects of prescribed rest. Previous research suggests that patients who have more severe concussions may benefit more from prescribed rest than those with less severe injuries.[59] Other subgroup analyses findings supported greater negative effects for certain symptom measures (SCAT5), shorter intervention time period (<28 days), and published studies. The subgroup analyses were hampered by small sample sizes (k < 10) for the comparison subgroups, and many studies did not account for or report specific subgroup information. Therefore, the subgroup analyses findings should be interpreted with caution.

Limitations

The current analysis was limited to 19 studies, because few clinical trials on concussion included sufficient data and details for a meta-analysis. In addition, many of the studies included in this analysis lacked additional details about the intervention groups, particularly for the patients assigned to the prescribed rest intervention groups, as this is typically the control group. Of note, a majority of studies did not report compliance data for assigned group interventions. In the absence of compliance data, it is likely that some of the patients in the prescribed rest groups may have engaged in physical and/or cognitive activity during the intervention period, thereby muting the potential negative effect of prescribed rest. Furthermore, the lack of diagnostic consensus for concussion, as well as comorbid conditions, leads to high levels of heterogeneity among those who receive diagnoses. Such heterogeneity likely confounds results of individual studies and therefore this meta-analysis. Our ability to conduct subgroup analyses was limited by the small sample sizes for comparisons of effects by study measures, age group, mechanism of injury, and publication status. Moreover, intervention data stratified by variables such as sex and concussion history are not commonly reported in the literature. Some studies included both male and female participants, whereas other studies enrolled only 1 sex or primarily 1 sex. Similarly, studies often enrolled patients across intuitive age groups such as children, adolescents, and young adults, which limited our ability to tease out potential age effects. With regard to our analytic approach, although we attempted to address publication bias using appropriate techniques in our search and analysis, 2 of the studies that met inclusion and exclusion criteria were published only as abstracts, suggesting that publication bias may have influenced the current findings.

CONCLUSION

Despite increasing empirical evidence regarding the potential negative effects of rest, prescribed rest is still a commonly used initial point of care and, in many cases, extended management strategy for patients with concussion.[45] To our knowledge, this study is the first to examine the aggregate effect of prescribed rest (vs more active rehabilitation) in patients with concussion. Overall, the current study's findings suggest that there is a small negative effect for prescribed rest on symptoms after concussion. This summary finding is consistent with growing clinical consensus promoting active interventions after concussion[29,43] and more recent RCTs in this area.[39] However, the small magnitude of the effect size, the lack of support for an effect of recovery time, and the relatively small overall number of studies that were eligible for inclusion highlight the ongoing concern regarding the quantity and rigor of clinical trials in concussion. Also, because most studies involved some period of initial, brief relative rest, we cannot infer the effects of early (ie, <48 hours) active interventions. The findings indicate that other factors such as younger age and sport-related mechanisms of injury were associated with a greater negative effect size for prescribed rest after concussion. Moving forward, additional RCTs and alternative designs, including platforms trials that evaluate the effects of rest and active interventions after concussion, are warranted. Of note, studies involving prescribed rest as a control or comparison group for concussion intervention trials may be fewer in number in the future, as evidence for a negative effect for prescribed rest continues to grow.

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