The effectiveness of wearable electronic device system (WEDS)-supported physical activity (PA) programs for cancer survivors: A meta-analysis of randomized controlled trials.

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Abstract

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Results: 46 randomized controlled trials, involving 3713 patients, were included in this meta-analysis. The results indicated that WEDS-supported PA programs improved objectively measured moderate-to-vigorous physical activity (MVPA), steps per day and quality of life, and decreased sedentary behavior of cancer survivors. Subgroup analysis revealed that the combination of tools (no less than 2 formats) in WEDS was effective in improving the subjectively reported PA and steps per day, decreasing sedentary behavior, and enhancing quality of life. Long-term (?12 weeks) interventions improved objectively measured MVPA and steps per day and decreased sedentary behavior.

Conclusions: We observed that WEDS-supported PA programs are promising for reducing sedentary behavior and improving the level of PA, sedentary behavior, steps per day, and QoL of cancer survivors but have no significant effect on BMI. In the future, the formats of partnering tools, the duration of intervention, and tailored exercise programs that benefit cancer survivors should be carefully considered when developing or updating WEDS-supported PA programs. Clinical Trial: CRD42024582905.

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Conclusion: We observed that WEDS-supported PA programs are promising for reducing sedentary behavior and improving the level of PA, sedentary behavior, steps per day, and QoL of cancer survivors but have no significant effect on BMI. In the future, the formats of partnering tools, the duration of intervention, and tailored exercise programs that benefit cancer survivors should be carefully considered when developing or updating WEDS-supported PA programs.

Registration: CRD42024582905.

1. INTRODUCTION

Owing to advancements in early detection and breakthroughs in cancer treatment, the number of long-term cancer survivors has significantly increased, transforming cancer into a chronic condition and becoming a growing global public health concern[1]. When cancer is considered a chronic disease, it is essential to cope with cancer survivors' self-management and increase their quality of life (QoL). However, cancer survivors often suffer from various symptom burdens, including reduced cardiorespiratory fitness, fatigue, sleep disturbances and emotional distress, which affect their quality of life. [1-7] These symptom burdens and decreased QoL are even associated with patient survival[8-11]. Keeping physically active has emerged as a promising lifestyle for cancer survivors. Physical activity (PA) refers to any bodily movement produced by skeletal muscles that requires energy expenditure[12]. For cancer survivors, adequate PA can improve their symptom burden and QoL[13]. However, when cancer survivors are diagnosed with cancer, their engagement in little or leisure PA significantly decreases, whereas their engagement in sitting increases, which negatively impacts their survival[14]. Barriers that prevent cancer survivors from participating in PA may include their symptom burden (such as pain, fatigue, and lymphedema), social factors (lack of time, motivation and support from health care professionals), and lack of information (recommendations on PA)[15]. Thus, it is essential to find an intervention that has the potential to encourage or remind cancer survivors to increase their level of PA and provide support to cancer survivors.

Digital health, defined as the use of 'digital technologies for health'[16], which include mobile health (mHealth) apps, electronic health records (EHRs), electronic medical records (EMRs), wearable electronic devices (WEDs), telehealth and telemedicine, and personalized medicine[17], is the global future. WEDs are any kind of electronic device designed to be worn on the user's body, such as an accessory or an implant[18]. With respect to behavior change techniques (BCTs)[19], interventions supported by WEDs have become increasingly prevalent among cancer survivors to increase their PA through the collection of physical and physiological information, continuous real-time self-health surveillance, and delivering stimulation for behavior change[20-23]. Moreover, WEDs can combine with partnering tools to form a wearable electronic device system (WEDS), where partnering tools include

telephone calls, short message services (SMSs), applications, or websites. Interventions supported by WEDS have been verified to be efficient intervention modalities and can offer an optional and novel approach to promote PA among cancer survivors [22, 24, 25].

In WEDS-supported PA programs, HCPs usually set PA goals for participants, WEDs play a role in self-monitoring and data collection, and the role of partnering tools is usually composed of patients' contact with health care professionals (HCPs) or timely feedback from HCPs (such as consulting, goal resetting and guidance)[25]. Although evidence suggests that WEDS-supported PA programs can benefit cancer patients by increasing PA levels and health-related outcomes (such as fatigue, aerobic fitness, and QoL), the results of existing studies on the effects of these programs have been inconsistent[20, 26, 27]. For example, Singh et al. reported that WEDS-supported PA programs led to a statistically significant increase in patients' daily step counts[20], whereas Teo et al. reported that there was no statistically significant difference between the two groups[26]. Additionally, in other forms of e-health-supported interventions for cancer survivors, the effectiveness varies with e-health type and intervention duration; for example, both Li et al. and Su et al. reported that the effectiveness of internet-based digital health interventions differed across different subgroups in terms of the format or duration of the intervention[28, 29]. Moreover, in previous studies, the role that partnering tools play has always been ignored. No researcher has investigated which types of partnering tools can better integrate with WEDs to improve their function. Furthermore, although most of these studies on our topic were published, the researchers focused only on specific types of cancer or discussed limited health-related indicators[26, 27].

Furthermore, the focus of most prior research in this area has predominantly been on examining feasibility, utility, or acceptability, and to our knowledge, no meta-analysis have focused on WEDS-supported PA programs, nor have they examined the various formats of partnership tools employed for improving the level of physical activity, body mass index (BMI), or quality of life and decreasing sedentary behavior.

Thus, the objectives of our meta-analysis are (1) to evaluate the effects of WEDS-supported PA programs on increasing PA-related outcomes and quality of life and (2) to explore which kind of WEDS is best and how long the intervention should be for cancer survivors.

2. METHOD

This meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement[30] and has been duly registered with the International Prospective Register of Systematic Reviews (PROSPERO) (registration number: CRD42024582905). As the data utilized in this research were exclusively sourced from prior publications, the need for ethical approval and informed consent was waived.

2.1. Search strategy

A comprehensive literature search was carried out, spanning from the advent of databases up until July 31, 2024. This search was conducted across five prestigious electronic databases: PubMed, EMBASE, Web of Science, CENTRAL, and MEDLINE, encompassing access to the complete text of the articles. The development of the search strategy was guided by the PICOS framework—encompassing Participants, Interventions, Comparisons, Outcomes, and Study design—along with the guidelines provided by the Cochrane Collaboration, to guarantee the integrity of the analysis. This strategy incorporates the use of medical subject headings (MeSH) terms, textual keyword searches, and Boolean logic operations; and it is supplemented by keywords, title or abstract terms, including words such as neoplasms, carcinomas, tumors, cancer, caregivers, physical activity trackers, wearable, telemedicine, and telerehabilitation (All the search strategies utilized are presented in Supplementary Material 1). The search was limited to studies with humans and randomized controlled trials and was conducted in English. Moreover, we engaged in a rigorous manual review of the bibliographies appended to the retrieved articles, thereby facilitating the identification and acquisition of supplementary pertinent scholarly works, which served to augment the depth of our analytical inquiry.

2.2. Study eligibility criteria

This meta-analysis considered studies for inclusion based on their adherence to the following criteria: (1) participants were survivors of any type of cancer, regardless of sex and cancer stage; (2) patients in the intervention group received WEDS-supported PA programs, including reminding cancer survivors to change their behavior, consulting with HCPs or receiving social support from other patients; (3) patients in the control groups received usual care or were on a waitlist; (4) the outcomes included at least one of the following indices—objectively measured PA, subjectively reported PA, sedentary behavior, QoL, BMI, without limitations on the measures used; (5) the publications were composed in the English language.; and (6) the studies were designed as randomized controlled trials (RCTs). Studies were excluded if full-text access was unavailable or if relevant data were incomplete.

2.3. Study selection and data extraction

The reference management software EndNote X9 was employed to import and screen the titles and abstracts of the studies, with duplicates being meticulously eliminated. To ascertain the studies' alignment with the inclusion criteria, two independent authors concurrently conducted a thorough screening of the titles and abstracts. Subsequently, they meticulously evaluated the full texts of the papers based on the predetermined eligibility criteria. Any discrepancies in the screening process

were reconciled through discussion or by consulting a third author. Data extraction from the included studies was performed independently by two authors, who meticulously recorded the information into a predefined data extraction template. This template encompassed a range of details, including the first author's name, the year of publication, the country of study conduct, the ages of participants (mean and standard deviation (SD)), the sample size (post-intervention for both experimental and control groups), the type of cancer diagnosed in the patients, the types of WEDs and associated tools used, the intervention content, the duration of the interventions, the outcome measures employed, and the timing of assessments.

2.4. Quality assessment

The methodological quality and risk of bias in the included studies were meticulously assessed by two independent reviewers, using the bias risk assessment tool provided in the Cochrane Handbook for Systematic Reviews of Interventions, Version 5.1.0. Seven pivotal domains are encompassed by the Cochrane bias risk tool 2 for randomized controlled trials: random sequence generation (selection bias), allocation concealment (selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias), selective reporting (reporting bias), and other potential biases. Each domain has three grades: “low risk” bias, “high risk” bias, and “unclear risk” bias. The Cochrane official Excel profile was used to automatically compute the overall risk. Consensus on disagreements was achieved through deliberation, or when necessary, by referring to a third author for resolution.

2.5. Data synthesis and analysis

Utilizing Review Manager 5.3, we carried out heterogeneity evaluations and conducted the meta-analysis. To quantify the intervention effects, we computed the standard mean difference (SMD) along with its corresponding 95% confidence interval (*CI*). The forest plots are presented. Statistical significance for the overall effect difference was established when the two-tailed P value was less than 0.05. In addition, we assessed the statistical heterogeneity of the included studies via the I^2 statistic and *P* value. Data were pooled and analyzed using a fixed-effects model when the I^2 statistic was 50% or less and the P value exceeded 0.1[31]; when these criteria were not met, suggesting the presence of substantial heterogeneity across studies, a random-effects model was employed to derive more conservative effect estimates. To evaluate the robustness and reliability of the pooled results, a sensitivity analysis was carried out, employing the method of one-study-out.

3. RESULTS

3.1. Search results and selection

The initial search across five electronic databases identified 4555 articles. After 1194 duplicates were

automatically and manually removed, 3361 articles were excluded on the basis of their titles and abstracts. Following the initial screening, the complete manuscripts of the remaining 153 articles were retrieved, with a final total of 46 studies being incorporated into the meta-analysis. The procedures for search and selection are delineated in Figure 1.

3.2. Description of included studies

3.2.1. Study characteristics

The attributes of the 46 studies that were incorporated into this analysis are delineated in Table 1. Each of these studies, conducted as randomized controlled trials, has been published within a span ranging from 2005[32] and 2024[33, 34] in eight countries, including the United States of America (31 studies)[32, 34-63], Canada (1 study)[64], the United Kingdom (2 studies)[65, 66], New Zealand (1 study)[67], Australia (6 studies)[33, 68-72], the Netherlands (2 studies)[73, 74], Korea (2 studies)[75, 76] and China (1 study)[77].

3.2.2. Characteristics of cancer survivors

A total of 3713 cancer survivors were enrolled in the studies, with the number of participants in each study ranging from 11[55] to 412[74]. The mean age (SD) of the included cancer survivors was between 12.7 (7.87)[43] and 73.79 (7.74)[55] years. In terms of the types of cancer, 19 studies enrolled participants diagnosed with a nonspecific type of cancer[33, 35-37, 43, 44, 46, 49, 57, 62, 63, 65-69, 71, 74, 77], and another 27 studies focused solely on one type of cancer, including breast cancer (15 studies)[32, 34, 41, 42, 47, 48, 50, 51, 53, 54, 56, 61, 64, 70, 72], colorectal cancer (six studies)[38, 39, 52, 58, 59, 75], prostate cancer (four studies)[45, 55, 60, 76], leukemia or lymphoma (one study)[40], and glioma (one study)[73].

3.2.3. Characteristics of WEDS-supported PA programs

In the included studies, the intervention duration ranged from 4 weeks[35] to 48 weeks[41], while the average duration was 13.4 weeks. The WEDS-supported PA programs consisted of two components: WEDs and partnering tools.

WEDs play a role in step counting, reminders, and data storage. The WEDs used in these studies included pedometers (n=13)[32, 46, 47, 51-53, 55, 56, 65, 67, 68, 74, 75], smart watches (n=4)[54, 64, 72, 73], breath monitors (n=1)[35], smart bands (n=25)[33, 34, 36-42, 44, 45, 48, 49, 57-63, 66, 69-71, 76], intelligent sports bracelets (n=1)[77], headbands (n=1)[50] and activity monitors, with no mention of the concrete type (n=1)[43].

Partnering tools in the WEDS differ in terms of reminders, consultation, education, and data transformation for researchers. The types of partnering tools used included websites/webpages (n=5)[41, 43, 68, 69, 74], applications (n=7)[35, 40, 48, 50, 54, 56, 76], telephone calls (n=13)[32, 46, 47, 51-53, 55, 61, 64, 65, 67, 72, 77], SMSs (n=2)[38, 66] or their combinations (n=21)[33, 34, 36, 37, 39, 42, 44, 45, 49, 57-60, 62, 63, 70, 71, 73, 75].

In 46 articles, the BCT used in interventions included goal setting, self-monitoring, feedback

and monitoring, and social support. All interventions used goal setting, self-monitoring, and feedback and monitoring, and eight studies[34, 38, 41, 45, 50, 55, 58, 63] used social support.

3.2.4. Characteristics of the controls

In 46 studies, the participants of 35 studies in the control groups received usual care[32-34, 37-40, 43-46, 48-60, 62, 65, 67, 69-71, 74-77], and 11 studies received wait lists[35, 36, 41, 42, 47, 61, 63, 64, 68, 72, 73] during the study period.

3.2.5. Outcome measures

Outcome measures encompassed a diverse array, with assessments occurring at varied intervals and across distinct follow-up periods for participants.

Objectively measured physical activity steps per day and sedentary behavior: Objectively measured physical activity[33, 34, 36, 37, 40, 42-45, 48, 49, 54, 57-59, 61, 62, 69-71, 74], steps per day[34, 36, 37, 40, 41, 45, 47, 54, 57, 58, 62, 66, 70] or sedentary behavior[36, 40, 44, 48, 49, 54, 57, 61, 70, 71] were mostly calculated via the ActiGraph accelerometer series. In addition, Anderson et al. used a Sensewear physical activity monitor to assess patients' objectively measured physical activity and steps per day[65]. Ferrante et al. used Fitbit to evaluate patients' objectively measured physical activity[41]. Pedometer was used to evaluate steps per day by Sajid et al. and Frensham et al.[55, 68].

Subjectively measured physical activity: Six scales were used in 15 studies to assess cancer survivors' subjectively measured physical activity: the International Physical Activity Questionnaire Short Form[65], the Community Healthy Activities Model Program for Seniors[39, 47, 52, 67], the International Physical Activity Questionnaire[56, 73, 76], the Short Questionnaire to Assess Health-Enhancing Physical Activity[74], the Godin Leisure-Time Exercise Questionnaire[57, 66, 75], and the Seven-Day Physical Activity Recall[32, 46, 51-53].

QoL: Nine scales were applied to assess the QoL of cancer survivors in 20 studies: Patient-Reported Outcome Measurement Information System[40], 36-item short from health survey-physical component[36, 51, 63, 67, 68], Quality of Life in Adult Cancer Survivors[41], EORTC QLG Core Questionnaire-30[46, 50, 56, 74, 76], Functional Assessment of Cancer Therapy-General[38, 77], Functional Assessment of Cancer Therapy-Breast[34, 48, 64], Functional Assessment of Cancer Therapy-Colorectal[52, 75], RAND-36 Measure of Health-Related Quality of Life[66], and Pediatric Quality of Life Inventory[43, 49].

3.3 Risk of bias

Utilizing the revised Cochrane risk-of-bias tool, the studies that utilized intention-to-treat analysis within the inclusion criteria were classified as follows: 25% (six studies)[33, 34, 41, 45, 67, 73] were deemed to have a low risk of bias, while 75% (18 studies)[32, 36, 38, 44, 47, 49, 51, 52, 57, 60, 61, 64, 66, 69, 71, 74, 75, 77] were identified as having some concerns bias. Furthermore, among the studies that utilized per-protocol analysis,

27% (comprising six studies)[37, 39, 54, 65, 68, 70] of the included studies were assessed as having a low risk of bias, whereas the remaining 68% (15 studies)[40, 42, 43, 46, 48, 50, 53, 55, 56, 58, 59, 62, 63, 72, 76] and 5% (one study)[35] were classified as having some concerns and high risk of bias, respectively. Concerns of risk of bias emerged due to the randomization process (33 of 47 studies)[32, 36, 38, 40, 42-44, 46-53, 55-64, 66, 69, 71, 72, 74-77] and measurement of the outcome (1 of 47 studies)[42]. A high risk of bias was associated with deviation from the intended interventions (1 of 47 studies)[35]. The assessments of the risk of bias are comprehensively delineated in Figure 2.

3.4. Meta-analysis results

The summary of all outcomes included in our meta-analysis are detailed in table 2

3.4.1. Objectively measured MVPA

3.4.1.1. Total effects of WEDS-supported PA programs

Investigators from 23 studies, encompassing a total of 1834 participants, quantified the influence of WEDS-supported PA programs on the objectively reported MVPA among cancer survivors, and the random-effects model employed for pooling the data yielded a significant improvement in the intervention groups. (SMD = 0.60, 95% *CI* [0.41, 0.79], $P < 0.01$) (Figure 3A-1). Additionally, the meta-analysis results remained stable after the omission of individual studies (Supplementary material 2).

3.4.1.2. Subgroup analysis

Studies grouped by partnering tool format suggested that WEDS-supported PA programs with both combined partnering tools (SMD = 0.62, 95% *CI* [0.38, 0.86], $I^2 = 70$) or single partnering tools (SMD = 0.65, 95% *CI* [0.46, 0.84], $I^2 = 67$) had significant differences in objectively measured MVPA (Figure 3A-2).

Upon categorizing the studies based on the duration of the intervention, the pooled results indicated that WEDS-supported PA programs with long-term (≥12 weeks) durations were effective in increasing objectively measured MVPA (SMD = 0.64, 95% *CI* [0.46, 0.82], $P < 0.01$) (Figure 3A-3).

3.4.2. Subjectively reported PA

3.4.2.1. Total effects of WEDS-supported PA programs

Data gathered from 15 studies, involving a collective total of 1967 participants, was employed to assess the efficacy of WEDS-supported PA programs in increasing subjectively reported PA. The results of the random effects model suggested that there was no significant difference between the experimental and control groups (SMD = 0.16, 95% *CI* [-0.24, 0.56], $P = 0.43$) (Figure 3B-1). Furthermore, Utilizing the one-study-out approach for sensitivity analysis, the findings reversed upon the exclusion of the study conducted by Ligible et al.[46], potentially due to the influence of bias

stemming from deviations from the intended intervention within that particular study (Supplementary material 2).

3.4.2.2. Subgroup analysis

In the pooled results of the formats of partnering tools, compared with the single format of partnering tools, the results in the combination subgroup (SMD = 0.67, 95% *CI* [0.02, 1.32], I^2 = 86%) were significantly different in subjectively reported PA (Figure 3B-2).

Upon categorizing the studies based on the duration of intervention, there was no significant difference in terms of increasing subjectively reported PA (Figure 3B-3).

3.4.3. Steps per day

3.4.3.1. Total effects of WEDS-supported PA programs.

Fifteen studies assessed the impact of WEDS-supported PA programs on the steps per day of cancer patients, random-effects model revealed significant difference between intervention and control groups. (SMD = 0.57, 95% *CI* [0.25, 0.89], *P* < 0.01) (Figure 3C-1). Utilizing the one-study-out approach for sensitivity analysis, the pooled findings remained robust upon the sequential exclusion of individual studies. (Supplementary material 2).

3.4.3.2. Subgroup analysis.

In the pooled results of the partnering tools of the WEDS-supported PA programs, compared with the single format of the partnering tools, the results of the combination subgroup (SMD = 0.64, 95% *C* [0.24, 1.04], I^2 = 84%) were significantly different in terms of the number of steps per day (Figure 3C-2).

The pooled findings from the subgroup analysis indicated a significant increase in steps per day when the duration of WEDS-supported PA programs was no less than 12 weeks (SMD = 0.59, 95% *CI* [0.25, 0.93], I^2 = 82%) (Figure 3C-3).

3.4.4. Sedentary behavior

3.4.4.1. Total effects of WEDS-supported PA programs.

Data gathered from 10 studies, involving a collective total of 747 participants, was employed to assess the efficacy of WEDS-supported PA programs in decreasing sedentary behavior. The results of the random effects model demonstrated that WEDS-supported PA programs significantly decreased cancer survivors' sedentary behavior (SMD = -0.60, 95% *CI* [-1.15, -0.05], *P* < 0.01) (Figure 3D-1). Utilizing the one-study-out approach for sensitivity analysis, the findings reversed upon the exclusion of the study conducted by Johnson et al., Lynch et al., McNeil et al. and Valle et al. [44, 48, 57, 70], potentially due to the influence of bias stemming from deviations from the intended intervention within that particular study. (Supplementary material 2).

3.4.4.2. Subgroup analysis.

In the pooled results for the partnering tools of WEDS-supported PA programs, compared with the single format of partnering tools, the combination subgroup (SMD = -0.31, 95% *CI* [-0.60, -0.01], I^2 = 64%) significantly differed in decreasing sedentary behavior (Figure 3D-2).

Similar to objectively measured MVPA, the pooled findings from the subgroup analysis indicated a significant reduction in sedentary behavior. when the duration was no less than 12 weeks (SMD = -0.74, 95% CI [-1.41, -0.07], I^2 = 93%) (Figure 3D-3).

3.4.5. BMI

3.4.5.1. Total effects of WEDS-supported PA programs.

Data gathered from 12 studies, involving a collective total of 1134 participants, was employed to assess the efficacy of WEDS-supported PA programs in decreasing BMI. The results of the random effects model demonstrated that there was no significant difference between the experimental and control groups (SMD = -0.07, 95% *CI* [-0.19, 0.05], *P* = 0.43) (Figure 3E-1). In addition, the pooled findings remained robust upon the sequential exclusion of individual studies. (Supplementary material 2).

3.4.5.2. Subgroup analysis.

In the pooled results of the subgroup analyses, there was no significant difference in BMI across the groups (Figure 3E-2).

3.4.6. Quality of life

3.4.6.1. Total effects of WEDS-supported PA programs.

Researchers from 19 studies assessed the effectiveness of WEDS-supported PA programs on the quality of life of cancer survivors, and the random effects model revealed a significant difference between the experimental and control groups in the pooled results (SMD = 0.30, 95% *CI* [0.07, 0.52], *P* < 0.05) (Figure 3F-1). A sensitivity analysis was conducted by using a one-study-out method. After one study (Li et al.[77]) that used the FACT-G to assess QoL was excluded, the pooled effects changed significantly, and the heterogeneity significantly decreased (SMD = 0.08, 95% *CI* [-0.02, 0.17], I^2 =0%) (Supplementary material 2). This might be because the FACT-G scores are much higher than those of the other scales.

3.4.6.2. Subgroup analysis.

In the pooled results of formats of partnering tools, compared with the single format of partnering tools, the combination subgroup (SMD = 0.38, 95% *CI* [0.03, 0.73], I^2 = 61%) had a significant improvement in QoL (Figure 3F-2).

Unlike the other outcomes, in the pooled results concerning the duration of intervention of

WEDS-supported PA programs, there was no subgroup difference across the two groups (Figure 3F-3).

4. Discussion

A total of 46 studies met the eligibility criteria for the meta-analysis. Compared with usual care or waitlists, WEDS-supported PA programs significantly improved cancer survivors' objectively measured MVPA, steps per day and QoL, while reducing sedentary behaviors, but had no significant effect on increasing self-reported PA or BMI.

4.1. Quality of evidence and methodology

Overall, evidence quality and methodology were rated moderate. Studies by Groups 24 employed intention-to-treat analysis, while Group 22 utilized per-protocol analysis. the quality of evidence and methodology was moderate. Utilizing the revised Cochrane risk-of-bias tool, it was determined that 26% (12 studies) were assessed with a low risk of bias, while 72% (33 studies) raised some concerns, and a mere 2% (one study) was deemed to have a high risk of bias. Specifically, 33 studies (72%) were flagged for potential bias related to the randomization process, and one study (2%) elicited concerns regarding bias in the measurement of outcomes. In detail, all studies were assessed as having either a low or unclear risk associated with the randomization process, primarily due to the fact that some investigators failed to provide comprehensive details on the randomization techniques or to adequately describe the allocation concealment methods. Consequently, the overall methodological quality was deemed moderate. This underscores the necessity for additional randomized controlled trials in the future, with a focus on more transparent reporting to enhance the robustness of the research findings.

4.2. Principle findings

4.2.1. PA-related outcomes

The results of this meta-analysis demonstrated that WEDS-supported PA programs significantly improved objectively measured MVPA, sedentary behaviors, steps per day and QoL in cancer survivors but had no significant effect on self-reported PA or BMI. The results of objectively measured MVPA, sedentary behaviors, and steps per day are consistent with the findings of previous studies[20].

For cancer survivors, these interventions serve as tracking devices (continuously collecting current activity), feedback tools (providing immediate information on activity level), and environmental cues (reminder to be active). With these continuous influences, patients' level of physical activity increases[78]. In addition, the partnering tools used in these interventions enable cancer survivors to record, report, and contact HCPs anywhere and anytime they need, ensuring

timely revision of exercise prescriptions and knowledge related to their disease and symptoms[33, 69]. Moreover, the opposite results between self-reported PA and objectively measured MVPA may be because patients tend to ignore their PA, which can be recorded automatically by devices. For BMI, the lack of a significant difference might be because a decrease in BMI requires more exercise training programs with higher intensity instead of just PA programs. Furthermore, diet management always plays a more important role in weight loss programs than exercise alone[79, 80].

The results of the subgroup analysis of the partnering tools revealed that objectively measured MVPA significantly improved in both the combination subgroup and the noncombination subgroup. The reason for this result may be that at the beginning of the interventions, the researchers all set PA goals for the participants and changed their goals according to their performance through the partnering tools; thus, the kinds of partnering tools may not affect their objectively measured MVPA. For subjectively reported PA, steps per day and sedentary behavior, the combination groups were significantly different. The reason may be that no less than two types of partnering tools can play a more comprehensive role, such as having the real-time conversation feature of telephones in conjunction with the real-time discussion of relevant knowledge via apps or websites. Through this type of multimedia stimulation, participants can receive more comprehensive reminders and encouragement to remain physically active. Moreover, we observed significant improvements in objectively measured MVPA, steps per day, and sedentary behavior among participants who received long-term (no less than 12 weeks) interventions, which is consistent with previous findings. Research has shown that longer-term interventions are conducive to forming a healthier lifestyle and developing habits if regular exercise is performed by patients[81, 82]. With respect to BMI, there was no significant difference in the use of partnering tools or the duration of the intervention. The reason for these results may be that regardless of the duration or means of partnering tools used, common PA is not enough to reduce BMI.

In brief, WEDS is promising for improving MVPA, sedentary behavior, and steps per day. Long-term interventions significantly improved these outcomes, but previous studies often failed to adequately consider the role of partnering tools, resulting in their underutilization and a missed opportunity to maximize the benefits for patients' PA engagement. Thus, attention should also be given to the choice of partnering tools and the duration of interventions when new WEDS-supported interventions are designed. This approach will enable the development of more effective WEDS-supported interventions. The reason for this is that previous studies often failed to adequately consider the role of partnering tools, resulting in their underutilization and a missed opportunity to maximize the benefits for patients' PA engagement.

4.2.2. Quality of life

This meta-analysis demonstrated that, compared with usual care or wait lists, WEDS-supported PA programs have a significant effect on the QoL of cancer survivors, which is consistent with the findings of previous studies[20]. The QoL assessed in our included studies was health-related quality of life (HRQoL), which comprises not only basic physical functioning but also the participation of patients, such as work-related activities and entertainment[83]. WEDS-supported PA programs significantly improved cancer survivors' inactive lifestyles; improved their self-efficacy and feelings of self-worth; increased their satisfaction with their lives; and affected their QoL indirectly[84]. Moreover, the appropriate social relationships, cancer and self-care education, and psychological support provided by partnering tools could help improve cancer survivors' QoL[85].

In the subgroup analysis, in terms of the formats of the partnering tools, there was a significant effect on the QoL in the combination group. The reason may be that the combination group significantly improved participants' level of PA, which then indirectly influenced their symptom burden and QoL. Furthermore, the combination group enables participants to gain multiple forms of access to obtain more psychological support from researchers or some partners via social media. Thus, participants' emotional distress improved, and their QoL improved[85].

When grouped by the duration of intervention, there was no significant difference in improving the QoL of cancer survivors in the two subgroups. The reason might be that subgroup analysis decreased the sample size in each subgroup. More studies whose duration of intervention is longer are needed.

In essence, WEDS-supported PA programs have the capacity to diminish cancer survivors' negative affective state and consequently enhance their QoL. Researchers should account for the duration of intervention when crafting WEDS-supported strategies. Additionally, further investigation is necessary to evaluate the effectiveness of partnering tools in meeting the needs of cancer survivors.

4.3. Limitations

This study has several limitations. First, heterogeneity existed due to different formats of partnering tools, durations of intervention, and types of cancer. Second, WEDs are usually commercial devices; although their production process has matured, whether they can be used in the clinic as normal still needs more trials, and commercial devices are at risk of producing publication bias. Additionally, a significant proportion of the research was conducted within Western nations, but reactions to the WEDS-supported PA program may be diverse among participants from different regions[86]. Ultimately, despite the implementation of an exhaustive search strategy that encapsulated both

cancer survivors and WEDS-supported PA programs within five key electronic databases, our efforts were impeded by studies featuring partial data and those from which full-text retrieval was not feasible. It is imperative, therefore, that the outcomes of this meta-analysis are interpreted with a critical awareness of these inherent limitations.

4.4. Implications

In this study, we quantitatively integrated the existing findings and found that WEDS-supported PA programs were conducive to improving the level of PA, daily steps, and quality of life and decreasing sedentary behavior among cancer survivors. The mechanisms by which WEDS-supported PA programs bring clinical benefits might include persistent reminders to patients to be actively physical, providing convenient access to consulting with health care professionals, collecting health-related data, recording electronic health records, and providing social groups for similar patients to communicate with each other[37, 40]. Thus, HCPs can use WEDS as a supplement to monitor patients' physiological data and manage patients, adjust patients' exercise prescriptions, and provide patients timely feedback and disease-related knowledge.

With increasing studies focusing on WEDs and other forms of eHealth as interventions to promote cancer survivors' PA, WEDS has the potential to become a valuable tool for HCPs and cancer survivors to be a novel reminder and management tool, and it can automatically sync data, thereby reducing the self-monitoring burden associated with web-based interventions[87]. However, we observed that certain aspects of the intervention, including the partnering tools formats and the duration of the intervention, influenced its efficacy. This underscores the need for further standardization to refine the WEDS-supported interventions framework. Moreover, many kinds of commercial WEDs have different tools and cannot share patient data. Furthermore, most of our included programs did not illustrate what kind of exercises were used as PA or explained the intensity of the PA. In the future, the formats of WEDs and partnering tools, as well as tailored exercise programs that benefit cancer survivors, should be carefully considered when developing or updating WEDS-supported PA programs.

5. Conclusion

WEDS-supported PA programs are a convenient and affordable method for serving cancer survivors as a reminder and record of their physical activity. This meta-analysis of randomized controlled trials revealed that WEDS-supported PA programs improved cancer survivors' level of PA, steps per day, and QoL while reducing sedentary behavior, but had no significant effect on BMI. Furthermore, it is essential to not only investigate additional partnering tools but also to develop culturally sensitive medical WEDS-supported interventions to enhance the well-being of cancer

survivors.

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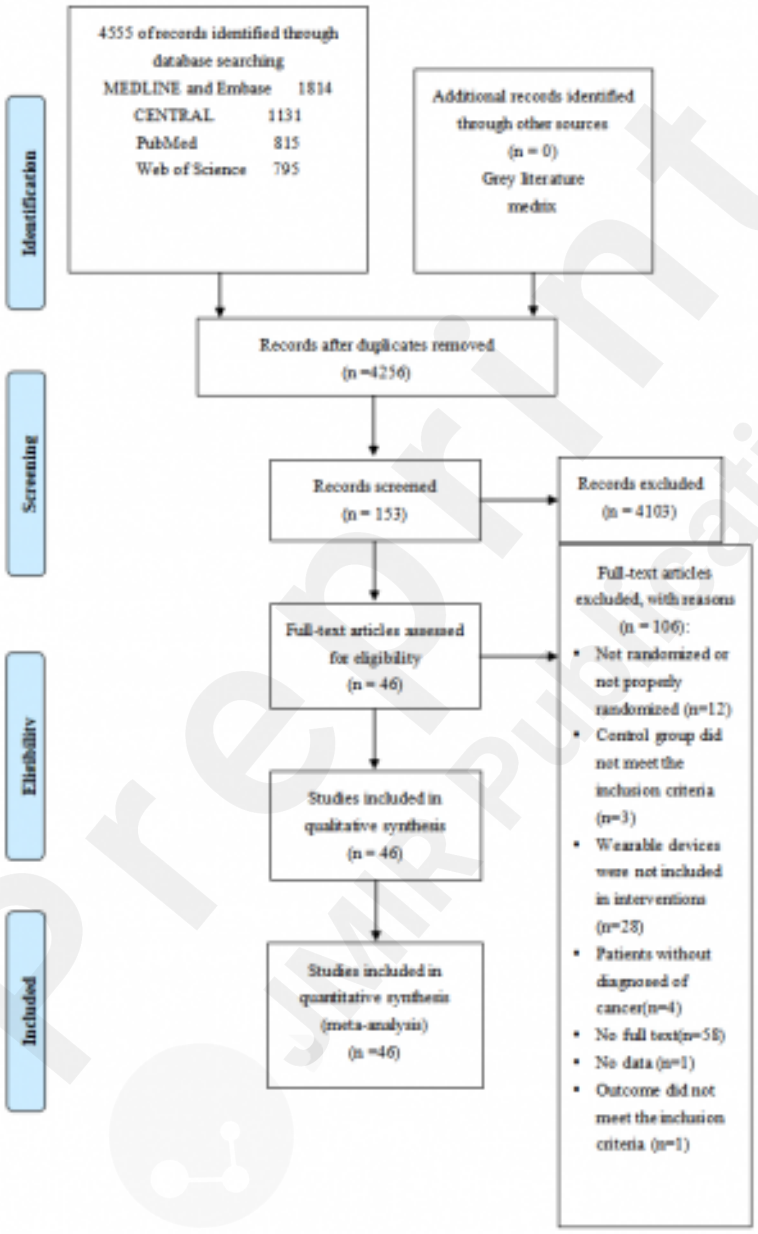
Supplementary Files

Figures

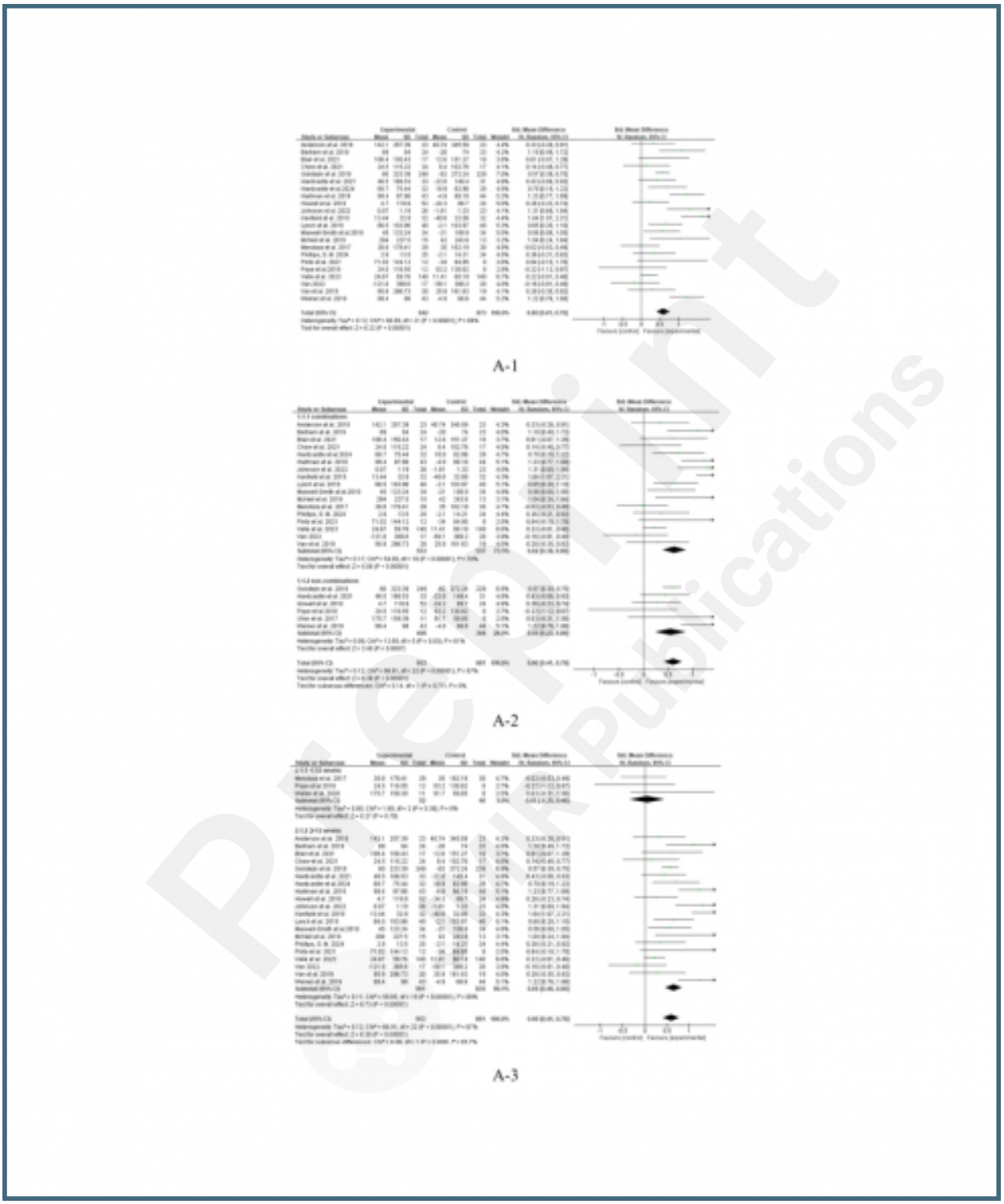
This figure shows our PRISMA flow diagram of the study selection process.

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram of the study selection process.

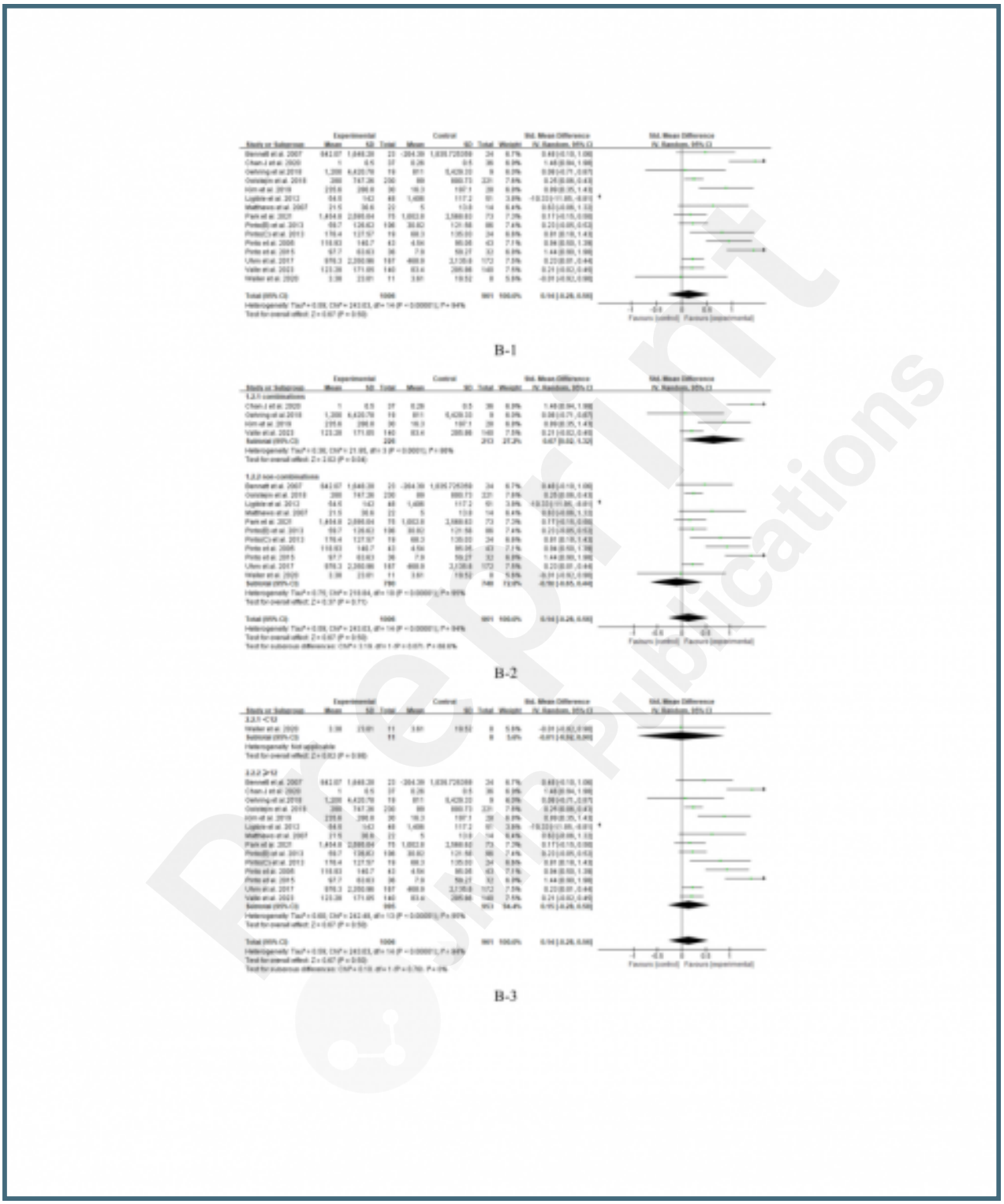


This figure shows the assessments of the risk of bias.

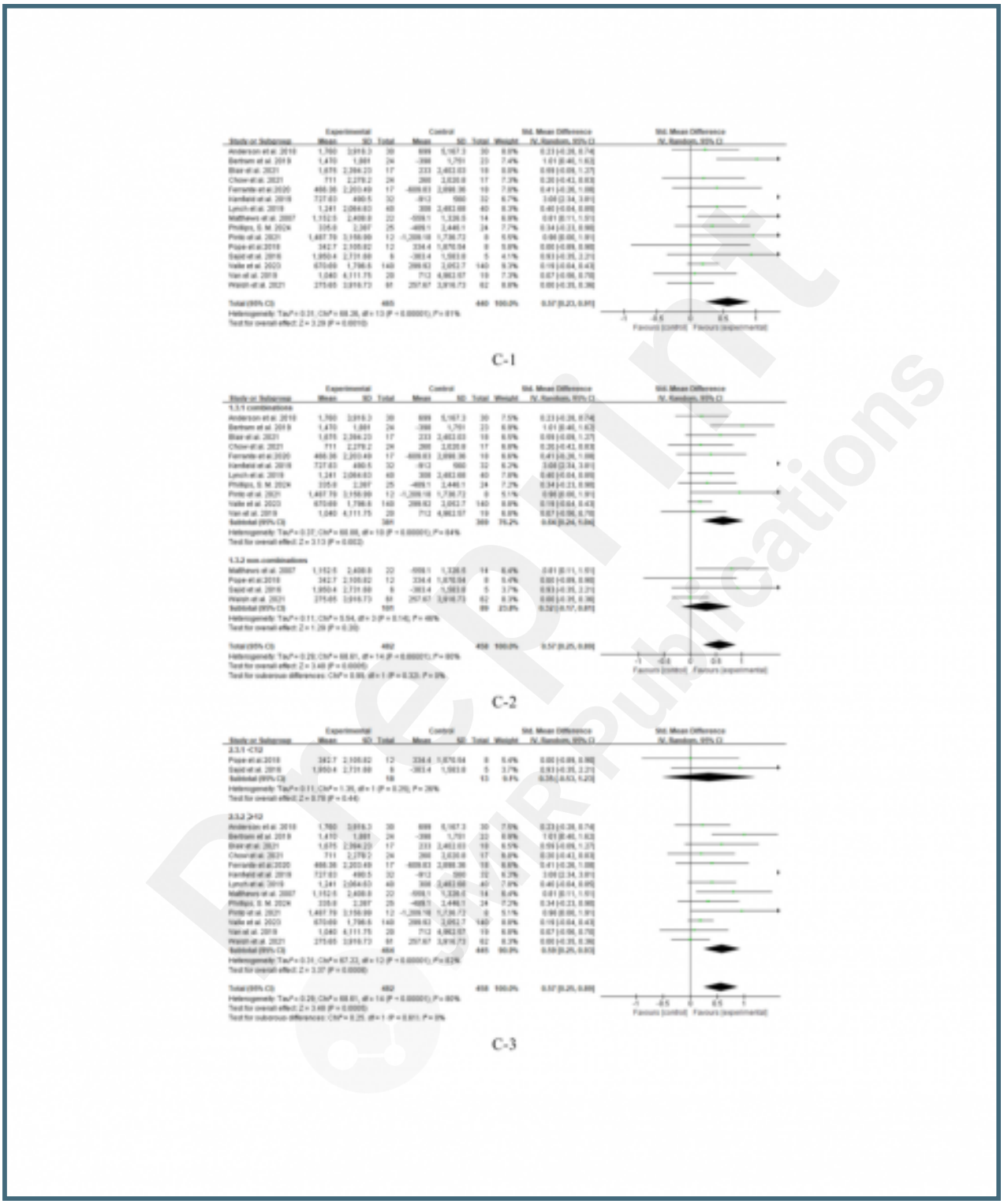
This figure shows the results of objectively-measured MVPA: 1- total effects, 2 - grouped by whether partnering tools were combinations, 3 - duration of interventions.



This figure shows the results of subjectively-reported PA: 1- total effects, 2 - grouped by whether partnering tools were combinations, 3 - duration of interventions.



This figure shows our results of steps per day: 1- total effects, 2 - grouped by whether partnering tools were combinations, 3 - duration of interventions.

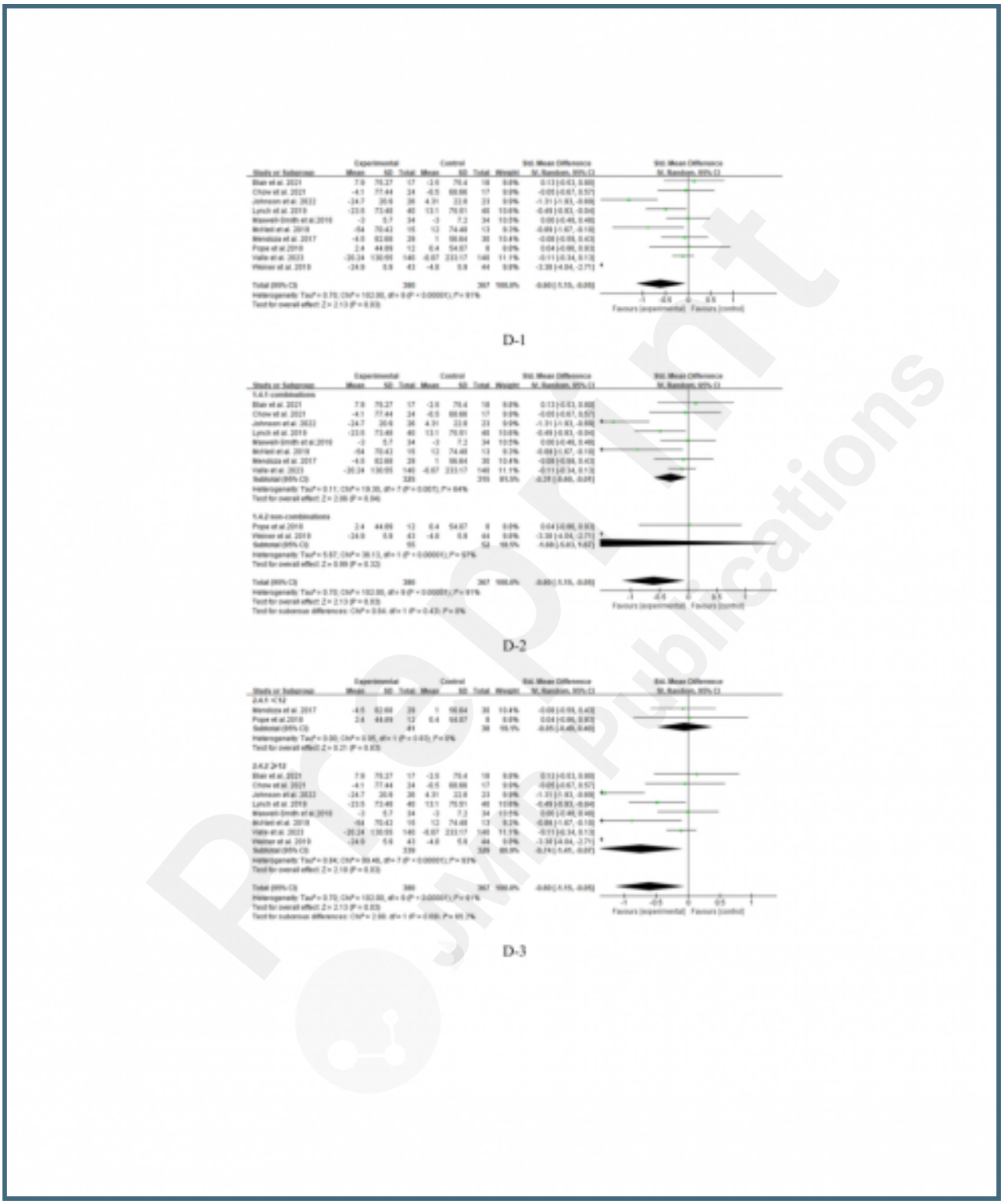


C-1

C-2

C-3

This figure shows our results of sedentary behavior: 1- total effects, 2 - grouped by whether partnering tools were combinations, 3 - duration of interventions.

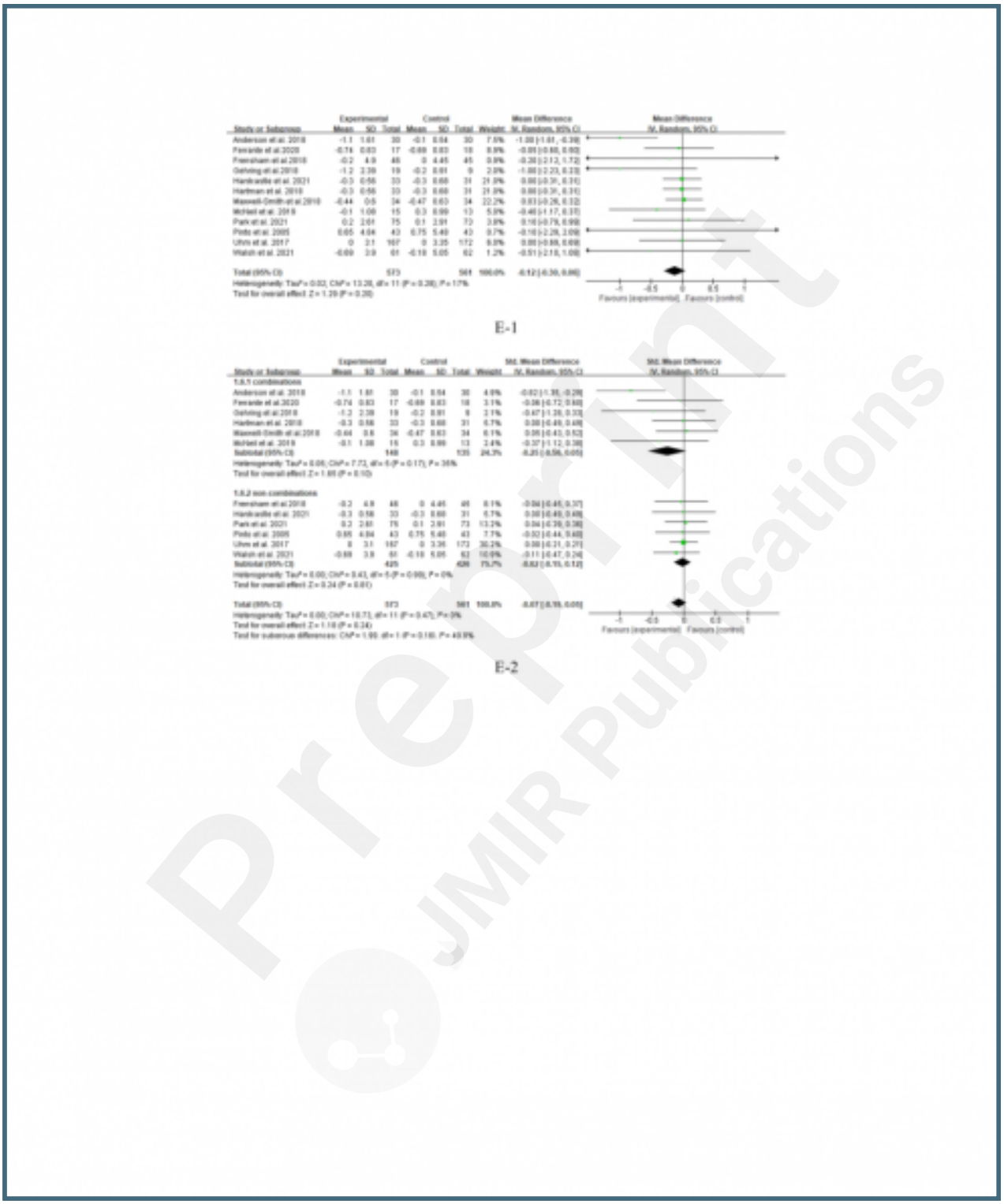


D-1

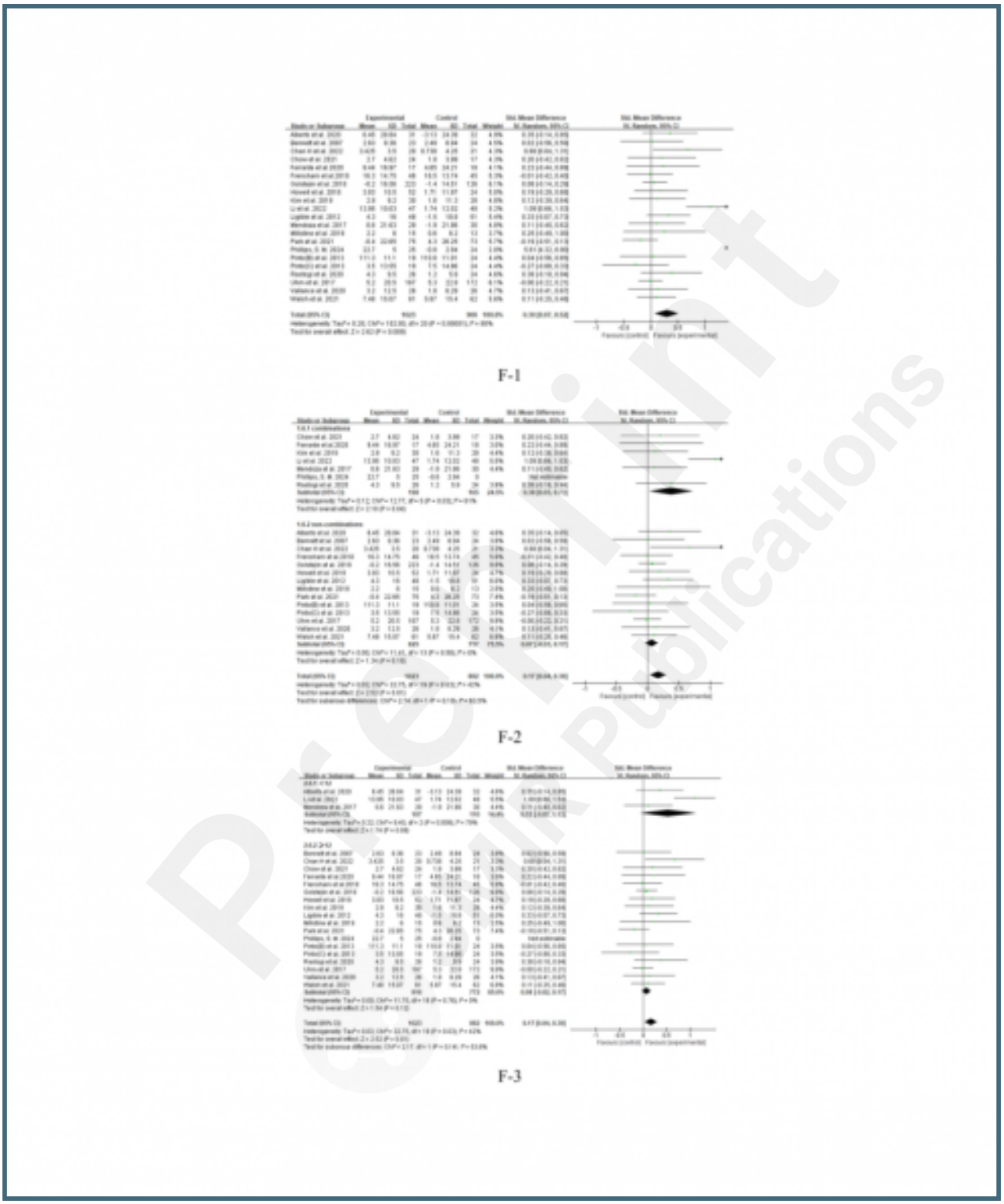
D-2

D-3

This fugure shows our results of BMI: 1- total effects, 2 - grouped by whether partnering tools were combinations, 3 - duration of interventions.



This fugure shows our results of quality of life: 1- total effects, 2 - grouped by whether partnering tools were combinations, 3 - duration of interventions.



F-1

F-2

F-3

Multimedia Appendixes

This appendix is a list of abbreviations.
URL: http://asset.jmir.pub/assets/403291c8f210755e53e784fcecf3ed80.docx

This table shows the characteristics of included researches.
URL: http://asset.jmir.pub/assets/25cf3a112023e3ba1a0e5eef2cc7104c.docx

This table shows the summary of all outcomes included in our meta-analysis.
URL: http://asset.jmir.pub/assets/c11bc1a09fd1183ef055ff7e0141c63c.docx

This appendix shows our search strategies.
URL: http://asset.jmir.pub/assets/d05efd0250ae267b50c4b1e1a99ed75c.docx

This appendix shows the results of sensitivity analysis.
URL: http://asset.jmir.pub/assets/f5c2e5e8d0fcfdd07ed336c836c322f3.docx