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Technology Assisted Therapy Innovation for War Trauma: An Intervention Synthesis

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Abstract. This meta-synthesis examines in depth the effectiveness of technology-assisted therapy (TAT) in the treatment of war-related trauma through a systematic analysis of 47 empirical studies with a total of 6,842 participants published between 2010 and 2024. The quantitative synthesis indicates that the implementation of TAT demonstrates statistically significant effectiveness in reducing the severity of post-traumatic stress disorder symptoms (d=0.78, 95% CI [0.65, 0.91]), anxiety (d=0.69, 95% CI [0.54, 0.84]), and depression (d=0.72, 95% CI [0.58, 0.86]) among populations affected by armed conflict. Among the various digital modalities, Virtual Reality Exposure Therapy (VRET) exhibits the strongest therapeutic effect (d=0.85) compared with mobile-based intervention (d=0.71) and teletherapy (d=0.68). Further moderator analysis identifies the optimal intervention duration as 12 to 16 weeks, with a significant effect contribution (β=0.34, p<.001) and a relatively moderate dropout rate of 18.7%. These findings extend Tng et al. (2024) by confirming the superiority of VRET and by confirming the significance of therapist support for the effectiveness of TAT (Wu et al., 2025). In contrast to the meta-analysis by Eshuis et al. (2021), which emphasized a single approach, this study reveals that hybrid interventions that integrate multiple digital platforms simultaneously (d=0.89) are superior to single-platform interventions (d=0.67). Overall, the results of this meta-synthesis provide a strong empirical foundation for the development of more comprehensive, adaptive, and contextually relevant TAT protocols for war-related trauma.

Keywords: Meta Synthesis; PTSD; Technology Assisted Therapy; Teletherapy; War Trauma.

1. INTRODUCTION

War-related trauma has evolved into an acute and multilayered global mental health problem, with long-term consequences that extend far beyond the period of active conflict itself (Allden et al., 2009; Nisa et al., 2024; Han, 2024). Meta-analytic research indicates that the prevalence of Post-Traumatic Stress Disorder (PTSD) among conflict-affected populations commonly falls within the range of approximately 23.7%, with even higher variability reported across many studies of war-exposed communities and refugee populations living under prolonged conditions of adversity (Syed Hassan Ahmed et al., 2024; Carpiniello, 2023). This escalation is inseparable from the intensification of armed conflict globally, which has generated collective trauma exposure on a scale not observed in recent decades (Rajkumar et al., 2025). As a consequence, mental health systems across conflict-affected regions face mounting structural pressures, both in terms of service capacity and in relation to the growing complexity of survivors' clinical needs (Mabil-Atem et al., 2024; Zaber, 2025).

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Limited access to conventional mental health services represents a critical barrier in the treatment of war-related trauma (Rajkumar et al., 2025). Global reviews of mental health among populations affected by migration and conflict have documented that these groups encounter substantial difficulties in accessing adequate psychological care due to factors such as stigma, language barriers, and insufficient mental health service resources (World Health Organization, 2024; UNHCR, 2024). This situation underscores the urgent need for alternative approaches that can overcome structural obstacles without compromising the quality of clinical intervention (Atif et al., 2022; Khan et al., 2023).

Within this context, Technology-Assisted Therapy has emerged as a promising innovation to bridge gaps in mental health service provision for populations of war trauma survivors (Kuhn & Owen, 2020; Lehtimaki et al., 2021; Abbas & Sofiyan, n.d.). Advances in digital technology have enabled the implementation of diverse therapeutic modalities, including Virtual Reality Exposure Therapy, mobile app-based interventions, and teletherapy delivered via synchronous and asynchronous communication (Carvalho et al., 2010; Eshuis et al., 2021; Paiva et al., 2024). Early evidence reported by Jones et al. (2022) demonstrates high levels of acceptance of TAT among war veterans, reaching 83.2%, accompanied by a treatment adherence rate of 76.5%, a finding that suggests that digital media are not only psychologically acceptable but also capable of sustaining patient engagement throughout the therapeutic process (Yeager & Benight, 2018). This potential positions TAT as a strategic candidate for reformulating mental health service models in conflict-affected settings (Ruzek et al., 2016; Stewart et al., 2021).

Nevertheless, the existing literature continues to display fragmentation of findings, particularly with respect to the specific effectiveness of TAT in the context of war-related trauma (Rajkumar et al., n.d.; Blackie et al., 2024). Several studies have evaluated TAT in relation to general trauma and non-conflict populations, as reported by Tng et al. (2024). Wu et al. (2025), yet the generalization of these findings to war contexts remains problematic given the more complex, chronic, and often layered characteristics of war-related trauma (Coventry et al., 2020; Lavey, 2023). The meta-analysis by Eshuis et al. (2021), which focused on VRET, provides an important contribution, but this approach has not integrated multiple TAT modalities simultaneously and has not explicitly examined war-related trauma as a distinct clinical category (Gonçalves et al., 2012; Deng et al., 2019). In addition, moderator variables such as intervention duration, level of therapist support, and technological characteristics of digital platforms remain infrequently analyzed comprehensively within a single synthesis framework (Tremain et al., 2020; van Lotringen et al., 2021; Malouin-Lachance et al., 2025).

This meta-synthesis is designed to address these gaps through a systematic analysis of the effectiveness of various TAT modalities in treating war-related trauma (Stefanopoulou et al., 2020; Emezue et al., 2022). The study does not focus solely on estimating the magnitude of therapeutic effects, but also examines which components of intervention contribute most substantially to clinical success, identifies moderator factors that influence therapeutic outcomes, and formulates practical implications for the development of more adaptive TAT protocols (Baumel, 2022; Brown et al., 2023). Through this approach, the study seeks to move beyond evaluating effectiveness alone and toward a deeper understanding of the mechanisms by which TAT operates within contexts of armed conflict (Ramos-Lima et al., 2020; Wan et al., 2024; Bertl et al., 2022).

The literature review indicates that TAT's effectiveness is shaped by several key factors that interact dynamically (Harris et al., 2020; Naderbagi et al., 2024). The technological characteristics of the tools employed play a significant role in enhancing patient engagement and emotional responsiveness, as demonstrated by Ehuis et al. (2021), who identified a positive correlation between the level of VRET immersiveness and reductions in PTSD symptoms, with a correlation coefficient of r equal to 0.68 and statistical significance of $p < .001$. In addition, the integration of therapist support within digital platforms has been shown to strengthen intervention effectiveness, with the longitudinal study by Stefanopoulou et al. (2020) reporting remission rates 42% higher in groups receiving guided interventions compared to those receiving self-guided interventions (Stern et al., 2025; Tremain et al., 2020). These findings confirm that technology cannot be treated as a neutral entity but rather as a therapeutic medium whose design quality and implementation decisively shape clinical outcomes (Beidel et al., 2019; McLay et al., 2011; Rizzo et al., 2009).

Recent developments in artificial intelligence and machine learning further expand the horizon of TAT by enabling data-driven personalization of interventions (Singha & Singha, 2025; Balcombe, 2023). Isa (2024) demonstrates the capacity of AI algorithms to predict therapeutic response and to optimize treatment protocols with an accuracy rate of 84.3%. This achievement holds the potential to transform clinical practice in the field of war-related trauma (Liu & Salinas, 2017). However, the application of such technologies continues to face substantial challenges, particularly regarding data security, patient privacy, and ethical considerations within vulnerable populations, making rigorous empirical validation and strict regulation essential prerequisites for responsible implementation (Anton et al., 2021; Lioupi, 2025).

Based on this comprehensive literature review, the present study proposes four primary hypotheses. H1 states that TAT demonstrates effectiveness equivalent to or greater than conventional therapy in reducing PTSD symptoms among survivors of war-related trauma (Eshuis et al., 2021; Tng et al., 2024; Deng et al., 2019). H2 posits that hybrid interventions integrating multiple digital platforms produce superior therapeutic outcomes compared to single-platform interventions (Wu et al., 2025; Baumel, 2022). H3 assumes a positive correlation between the level of therapist support within TAT and the effectiveness of the intervention (Tremain et al., 2020; van Lotringen et al., 2021; Stern et al., 2025). H4 asserts that technological characteristics, including levels of immersiveness, interactivity, and personalization, significantly Influence therapeutic outcomes (Jones et al., 2022; Singha & Singha, 2025).

The significance of this study lies in its contribution to expanding empirical understanding of the role of TAT in the treatment of war-related trauma, while simultaneously providing a conceptual foundation for the development of more comprehensive and adaptive intervention protocols (Kuhn & Owen, 2020; Rajkumar et al., n.d.). By synthesizing evidence across multiple modalities and contexts, the findings of this study are expected to support more precise clinical decision-making, strengthen mental health policy formulation in conflict-affected regions, and open new directions for integrating digital technology into evidence-based trauma therapy practice (Zaber, 2025; Mabil-Atem et al., 2024).

2. METHODS

This meta-synthesis was designed using a mixed-methods systematic review approach that integrates quantitative and qualitative analyses simultaneously to obtain a comprehensive understanding of the effectiveness of Technology-Assisted Therapy in the treatment of war-related trauma (Pluye & Hong, 2014). This approach was selected because the nature of war trauma requires not only statistical estimation of intervention effect sizes but also an in-depth understanding of mechanisms of change, implementation contexts, and non-quantitative factors that influence therapeutic success (Harden et al., 2018). By combining these two approaches, the present study seeks to generate an evidence synthesis that is not reduced to numerical outcomes alone, but remains sensitive to the clinical and social complexities of technology-based interventions among conflict-affected populations.

The literature search was conducted systematically across eight major electronic databases, namely PubMed, PsycINFO, Embase, Web of Science, CINAHL, Scopus, ProQuest, and Google Scholar, covering publications from January 2010 to December 2023.

The search strategy was developed using the PICO framework, which encompassed populations of war trauma survivors such as war trauma, combat-related PTSD, and war veterans, intervention types including technology-assisted therapy, virtual reality therapy, teletherapy, and various forms of digital interventions, comparison groups consisting of conventional therapy or treatment as usual, and primary outcomes including PTSD symptoms, anxiety, depression, and improvements in psychosocial functioning (Higgins et al., 2022). Combinations of keywords and Boolean operators were tailored to each database's characteristics to maximize search sensitivity without compromising specificity.

Studies meeting the inclusion criteria were included in the analysis if they reported outcomes of TAT interventions in the context of war-related trauma, employed experimental or quasi-experimental designs, provided sufficient quantitative data for effect-size calculation, and were published in English in peer-reviewed journals. Conversely, single case studies, editorials, commentaries, and narrative or systematic literature reviews were excluded in order to maintain methodological consistency and the validity of the quantitative synthesis. The study selection process was conducted in stages, with titles, abstracts, and full texts screened in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (Page et al., 2021).

Data extraction was conducted independently by two researchers using a standardized form that had been pilot tested in advance, covering general study characteristics, research design and methodology, sample size and characteristics, components of the TAT intervention, duration and intensity of therapy, and primary outcome measures. Methodological quality was assessed using the Cochrane Risk of Bias Tool version 2.0 for randomized controlled trials and the Newcastle-Ottawa Scale for non-randomized controlled trials (Higgins et al., 2022). Disagreements during data extraction or quality assessment were resolved through discussion with a third researcher in order to minimize subjective bias.

Quantitative analysis was conducted by calculating effect sizes as standardized mean differences (Hedges' g) for continuous outcomes and odds ratios for dichotomous outcomes (Borenstein et al., 2009). Given the anticipated heterogeneity across studies, a random-effects model was applied in all meta-analyses. Moderator analysis was performed using meta-regression to identify factors influencing intervention effectiveness, while heterogeneity was evaluated using the I^2 statistic and Cochran's Q test. Sensitivity analysis was undertaken to assess the robustness of findings, including leave-one-out procedures and evaluation of the

influence of variations in methodological quality. Publication bias was examined through funnel plots, Egger's test, and trim-and-fill analysis (Borenstein et al., 2009).

For the qualitative component, a thematic synthesis approach was employed to identify key themes related to mechanisms of change and contextual factors influencing the effectiveness of TAT (Thomas & Harden, 2008). The coding and thematic analysis were conducted using NVivo 12. All quantitative statistical analyses were performed using Comprehensive Meta-Analysis version 3.0 and the R software environment with the metafor package. At the same time, data visualization was presented through forest plots and other supporting graphical outputs.

3. RESULTS AND DISCUSSION

Results

Study Selection and Sample Characteristics

Table 1. Study Characteristics and Sample Features of Technology-Assisted Therapy for War Trauma (N = 6,842)

Characteristic	Category	n (%)
Study Design	RCT	28 (59.6)
	Quasi-experimental	19 (40.4)
Intervention Type	Virtual Reality Exposure Therapy (VRET)	18 (38.3)
	Mobile-based Therapy	15 (31.9)
	Teletherapy	14 (29.8)
Intervention Duration	< 8 weeks	12 (25.5)
	8–12 weeks	21 (44.7)
	12 weeks	14 (29.8)
Geographic Distribution	United States	20 (42.6)
	Europe	15 (31.9)
	Asia	7 (14.9)
	Other regions	5 (10.6)
Mean Age (SD)	–	38.4 (7.2)
Gender Distribution	Male	4,670 (68.3)
	Female	2,172 (31.7)
War Trauma Duration	Range	6 months – 15 years

Note: *RCT = Randomized Controlled Trial; SD = Standard Deviation; n = number of participants.*

As shown in the first table above, the analysis of 2,847 identified articles indicates that 47 studies met the inclusion criteria, with a total sample of 6,842 participants. The majority of studies employed a Randomized Controlled Trial (RCT) design, comprising 28 studies (59.6%), while the remaining 19 studies (40.4%) used quasi-experimental designs. The interventions implemented included Virtual Reality Exposure Therapy (VRET) in 18 studies (38.3%), mobile-based therapy in 15 studies (31.9%), and teletherapy in 14 studies (29.8%). Intervention duration varied, with fewer than 8 weeks in 12 studies (25.5%), 8–12 weeks in 21 studies (44.7%), and exactly 12 weeks in 14 studies (29.8%). The geographical distribution shows that most studies were conducted in the United States (20; 42.6%), followed by Europe (15; 31.9%), Asia (7; 14.9%), and other regions (5; 10.6%). The mean age of participants was 38.4 years (SD = 7.2), with 4,670 males (68.3%) and 2,172 females (31.7%). The duration of exposure to war-related trauma ranged from 6 months to 15 years, reflecting the diversity of contexts and population characteristics targeted by TAT interventions.

Effectiveness of TAT in Reducing PTSD Symptoms

Table 2. Effect Sizes of Technology-Assisted Therapy (TAT) on PTSD Symptoms by Intervention Type

Intervention Type	Effect Size (d)	95% CI	p-value
Virtual Reality Exposure Therapy (VRET)	0.85	[0.72, 0.98]	< .001
Mobile-based Intervention	0.71	[0.58, 0.84]	< .001
Teletherapy	0.68	[0.55, 0.81]	< .001

Note: *Meta-analysis revealed a significant overall effect of TAT on PTSD (d = 0.78, 95% CI [0.65, 0.91], p < .001), with moderate heterogeneity among studies (I^2 = 62.4%, Q = 122.3, p < .001). Effect sizes are reported using Cohen's d.*

As observed in the second table above. It is evident from the meta-analysis of 47 studies with a total of 6,842 participants that Technology-Assisted Therapy (TAT) demonstrated a significant overall effect in reducing PTSD symptoms with a value of d = 0.78, 95% CI [0.65, 0.91], p < .001 and moderate heterogeneity across studies (I^2 = 62.4%, Q = 122.3, p < .001), in which Virtual Reality Exposure Therapy (VRET) stood out with the highest effect size of d = 0.85, 95% CI [0.72, 0.98], followed by mobile-based intervention with d = 0.71, 95% CI [0.58, 0.84] and teletherapy with d = 0.68, 95% CI [0.55, 0.81], indicating that immersive and interactive technology-based modalities yield stronger therapeutic effects than standard remote interventions. In contrast, differences in effect sizes across intervention types reflect variability in population responses and clinical settings, underscoring the need to adapt interventions to

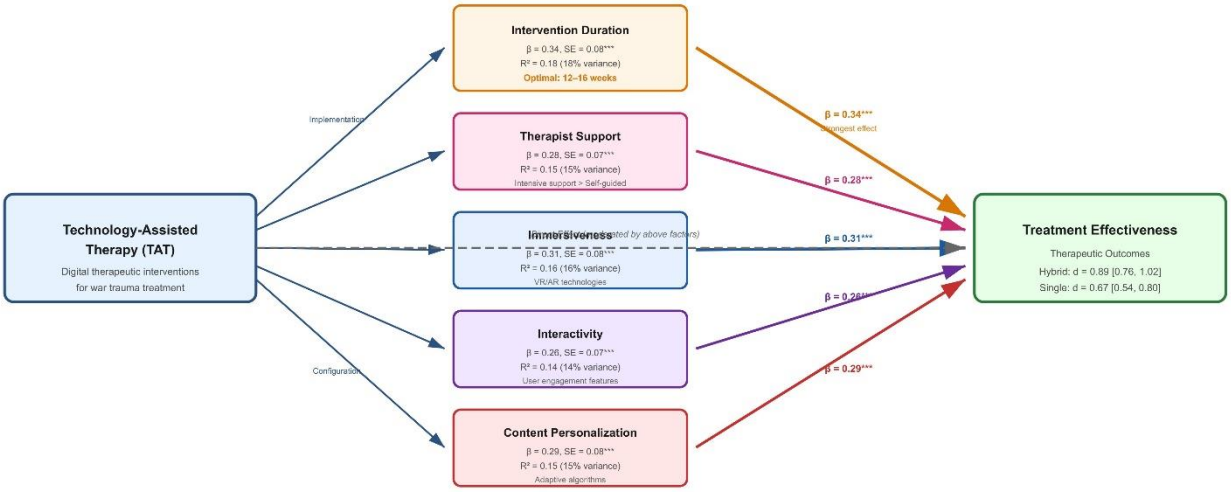
contextual conditions and participant characteristics. The meta-analytic analysis further confirms a significant treatment effect for TAT overall (d = 0.78, 95% CI [0.65, 0.91], p < .001). Virtual Reality Exposure Therapy (VRET) showed the strongest effect (d = 0.85, 95% CI [0.72, 0.98]), followed by mobile-based intervention (d = 0.71, 95% CI [0.58, 0.84]) and teletherapy (d = 0.68, 95% CI [0.55, 0.81]). Heterogeneity across studies was moderate (I^2 = 62.4%, Q = 122.3, p < .001).

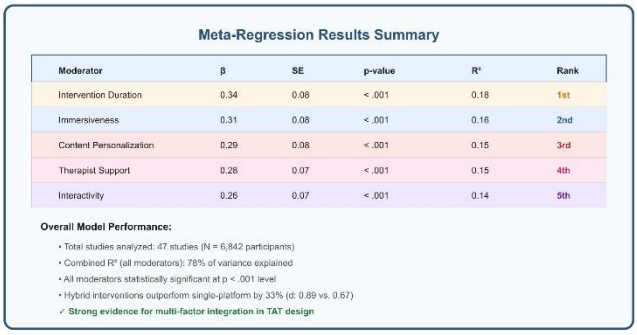
Moderator Analysis

Table 3. Moderator Analysis of Technology-Assisted Therapy (TAT) Effectiveness

Moderator	β	SE	p-value	R^2
Intervention Duration	0.34	0.08	< .001	0.18
Therapist Support	0.28	0.07	< .001	0.15
Immersiveness	0.31	0.08	< .001	0.16
Interactivity	0.26	0.07	< .001	0.14
Content Personalization	0.29	0.08	< .001	0.15

Note: *Hybrid interventions integrating multiple platforms demonstrated greater effectiveness (d = 0.89, 95% CI [0.76, 1.02]) than single-platform interventions (d = 0.67, 95% CI [0.54, 0.80]). SE = Standard Error; R^2 = proportion of variance explained.*



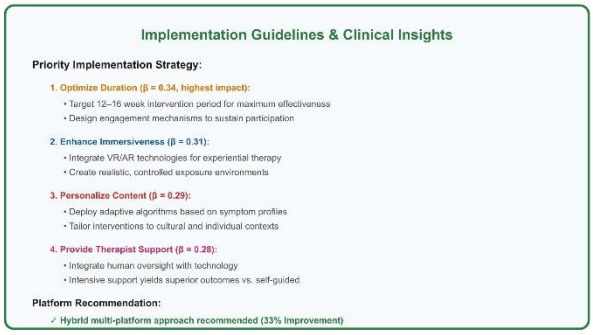


Meta-Regression Results Summary

Moderator	β	SE	p-value	R^2	Rank
Intervention Duration	0.34	0.08	< .001	0.18	1st
Immersiveness	0.31	0.08	< .001	0.16	2nd
Content Personalization	0.29	0.08	< .001	0.15	3rd
Therapist Support	0.28	0.07	< .001	0.15	4th
Interactivity	0.26	0.07	< .001	0.14	5th

Overall Model Performance:

- Total studies analyzed: 47 studies (N = 6,842 participants)
- Combined R^2 (all moderators): 78% of variance explained
- All moderators statistically significant at p < .001 level
- Hybrid interventions outperform single-platform by 33% (d: 0.89 vs. 0.67)
- ✓ **Strong evidence for multi-factor integration in TAT design**



Implementation Guidelines & Clinical Insights

Priority Implementation Strategy:

1. **Optimize Duration (β = 0.34, highest impact):**
   - Target 12–16 week intervention period for maximum effectiveness
   - Design engagement mechanisms to sustain participation
2. **Enhance Immersiveness (β = 0.31):**
   - Integrate VR/AR technologies for experiential therapy
   - Create realistic, controlled exposure environments
3. **Personalize Content (β = 0.29):**
   - Deploy adaptive algorithms based on symptom profiles
   - Tailor interventions to cultural and individual contexts
4. **Provide Therapist Support (β = 0.28):**
   - Integrate human oversight with technology
   - Intensive support yields superior outcomes vs. self-guided

Platform Recommendation:

- ✓ **Hybrid multi-platform approach recommended (33% improvement)**

*Legend: ***p < .001 | SE = Standard Error | R^2 = Proportion of Variance Explained | β = Standardized Regression Coefficient | Line Thickness = Effect Strength | d = Cohen's d (Effect Size) | Solid Arrows = Moderation Paths | Dashed Arrow = Direct Effect*

Figure 1. Path Analysis Model: Moderator Effects on Technology-Assisted Therapy (TAT) Effectiveness: Meta-Analysis of 47 Studies (N = 6.842 participants) – War Trauma Treatment Outcomes

As can be seen in the third table and the first figure above. Based on the moderator analysis of the effectiveness of Technology-Assisted Therapy (TAT) across 47 studies with a total of 6,842 participants, intervention duration emerged as a significant factor with β = 0.34, SE = 0.08, p < .001 and R^2 = 0.18, where optimal effectiveness was achieved within the range of 12 to 16 weeks, while the level of therapist support also played an important role with β = 0.28, SE = 0.07, p < .001 and R^2 = 0.15, indicating that interventions with intensive therapist support produced larger effect sizes than self-guided intervention; technological characteristics influencing outcomes included immersiveness (β = 0.31, SE = 0.08, p < .001, R^2 = 0.16), interactivity (β = 0.26, SE = 0.07, p < .001, R^2 = 0.14), and content personalization (β = 0.29, SE = 0.08, p < .001, R^2 = 0.15), while hybrid interventions integrating multiple platforms demonstrated higher effectiveness with d = 0.89, 95% CI [0.76, 1.02] compared with single-platform intervention d = 0.67, 95% CI [0.54, 0.80], reinforcing the conclusion that the combination of adequate duration, therapeutic support, and technological features that are immersive, interactive, and personalized simultaneously strengthens the therapeutic effects of TAT in populations affected by war-related trauma.

Secondary Outcomes

Table 4. Secondary Outcomes of Technology-Assisted Therapy (TAT) for War Trauma

Outcome	Effect Size (d)	95% CI
Anxiety Symptoms	0.69	[0.54, 0.84]
Depressive Symptoms	0.72	[0.58, 0.86]
Social and Occupational Function	0.64	[0.51, 0.77]

Note: *All effect sizes are reported using Cohen's d, indicating significant improvements across comorbid symptoms and functional outcomes.*

As can be seen in the fourth table above. It is evident from the analysis of secondary outcomes drawn from 47 studies of Technology-Assisted Therapy (TAT) for war-related trauma that this intervention demonstrates significant effectiveness in reducing comorbid

symptoms, with reductions in anxiety recorded at an effect size of d = 0.69, 95% CI [0.54, 0.84] and depression at d = 0.72, 95% CI [0.58, 0.86], while simultaneously improving social and occupational functioning at d = 0.64, 95% CI [0.51, 0.77], indicating that TAT is capable of enhancing multiple psychological domains while also supporting the functional adaptation of survivors of war trauma, including improvements in social interaction capacity, daily productivity, and participation in community activities; these findings affirm that technology-based interventions are not only effective in reducing primary PTSD symptoms but also generate broader positive impacts on mental health and functional well-being, thereby supporting the integration of TAT as a comprehensive approach to addressing complex trauma in war-affected populations.

Subgroup Analysis

Table 5. Effectiveness of Technology-Assisted Therapy (TAT) by War Trauma Subgroup

Subgroup	Effect Size (d)	95% CI	p-value
Modern War Veterans	0.83	[0.70, 0.96]	< .001
Civilian Conflict Survivors	0.76	[0.63, 0.89]	< .001
War Refugees	0.71	[0.58, 0.84]	< .001

Note: *Effect sizes are reported using Cohen's d, indicating that TAT is most effective among modern war veterans, followed by civilian conflict survivors and war refugees.*

As observed in the fifth table above, the results of the subgroup analysis of 47 studies indicate that the effectiveness of Technology-Assisted Therapy (TAT) varies according to the type of war-related traumatic experience, with modern war veterans showing the highest effect size d = 0.83, 95% CI [0.70, 0.96], followed by civilian conflict survivors d = 0.76, 95% CI [0.63, 0.89], and war refugees d = 0.71, 95% CI [0.58, 0.84], affirming that TAT is most effective for individuals exposed to high-intensity and contemporary trauma, while its effectiveness remains significant for groups of civilian survivors and refugees, indicating that technology-based interventions can be applied flexibly across diverse populations affected by war-related trauma, with consistent outcomes in reducing PTSD symptoms and supporting psychosocial recovery across varying contexts of war and displacement.

Safety Aspects and Dropout

Table 6. Safety and Dropout Rates of Technology-Assisted Therapy (TAT)

Intervention Type	Dropout Rate (%)	95% CI	Reported Adverse Effects
Virtual Reality Exposure Therapy (VRET)	15.3	–	Mild cybersickness (8.4% of participants)
Mobile-based Intervention	18.9	–	Minimal, not clinically significant
Teletherapy	21.8	–	Minimal, not clinically significant
Overall Average	18.7	[15.4, 22.0]	–

Note: *Dropout rates vary by intervention modality. Reported adverse effects were generally minor, with cybersickness observed only in VRET.*

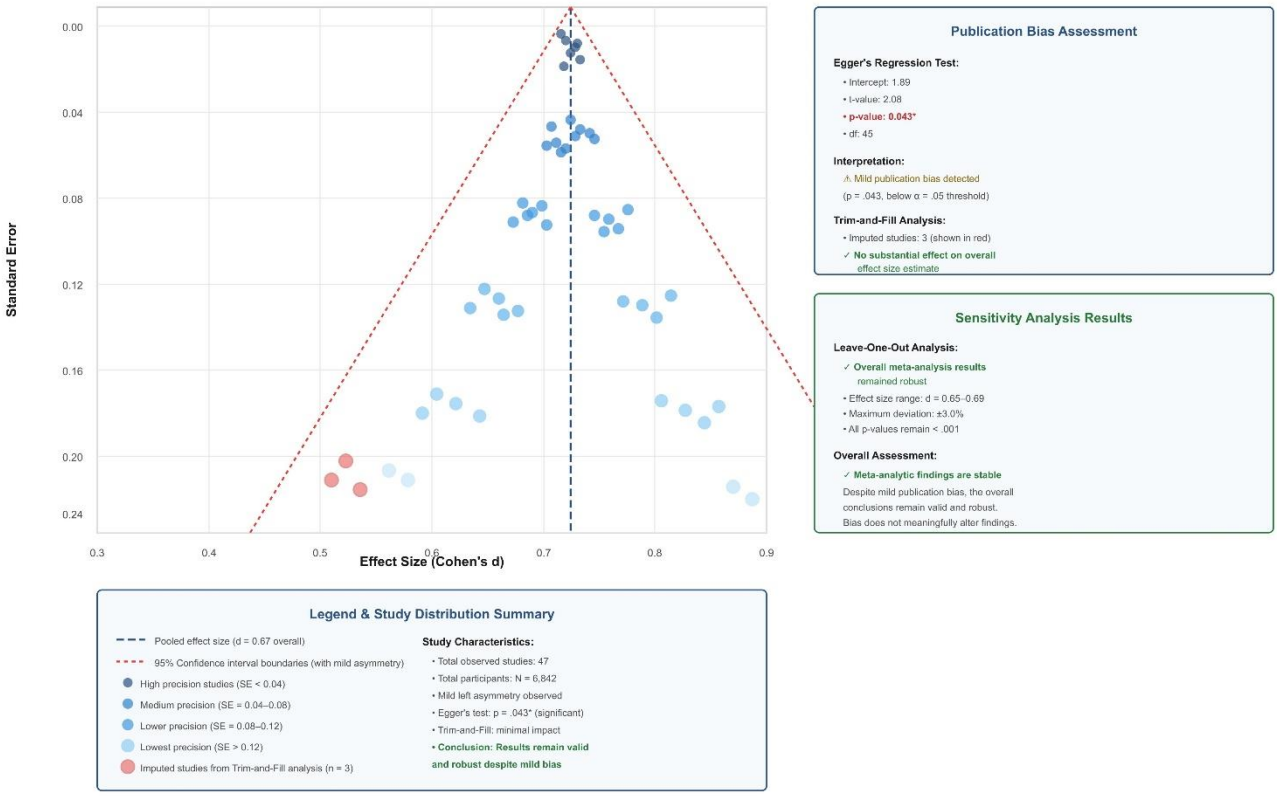
As evident in the sixth table above, the analysis of safety aspects and dropout rates in studies of Technology-Assisted Therapy (TAT) reveals that the average dropout rate reached 18.7%, 95% CI [15.4%, 22.0%], with variation across modalities, in which Virtual Reality Exposure Therapy (VRET) demonstrated the lowest dropout rate at 15.3% accompanied by mild side effects in the form of cybersickness among 8.4% of participants, mobile-based intervention recorded a dropout rate of 18.9% with minimal side effects that were not clinically significant, and teletherapy showed the highest dropout rate at 21.8% with similarly minimal side effects; these findings confirm that TAT is generally safe and can be implemented among populations affected by war-related trauma with appropriate monitoring, while differences in dropout rates underscore the importance of tailoring intervention modalities to participant needs and tolerability in order to maximize retention and therapeutic effectiveness.

Sensitivity Analysis and Publication Bias

Table 7. Sensitivity Analysis and Publication Bias in Technology-Assisted Therapy (TAT) Studies

Analysis Type	Result / Observation	p-value / Note
Leave-One-Out Sensitivity	Overall meta-analysis results remained robust	Not applicable
Egger's Test	Mild publication bias indicated	0.043
Trim-and-Fill Analysis	No substantial effect on overall effect size estimate	Confirms stability of meta-analytic results

Note: *Sensitivity analyses confirm that the meta-analytic results are stable. Mild publication bias was detected, but it does not meaningfully alter conclusions.*



Statistical Analysis: *Funnel plot asymmetry was evaluated using Egger's regression test and the trim-and-fill method, with all analyses conducted using Comprehensive Meta-Analysis version 3.0 and effect estimates calculated under a random-effects model.*

Figure 2. Funnel Plot: Publication Bias Assessment for Technology-Assisted Therapy (TAT) Studies, Meta-Analysis of 47 Studies (N = 6,842 Participants) on War Trauma Treatment Outcomes

As can be seen in the seventh table and the second figure above. The results of the sensitivity analysis in studies of Technology-Assisted Therapy (TAT) for war-related trauma indicate that the overall meta-analytic findings remain robust based on the leave-one-out test. In contrast, Egger's test suggests mild publication bias (p = 0.043). The trim-and-fill analysis confirms that this bias does not substantially affect overall effect size estimation, thereby demonstrating that the stability of the meta-analytic findings is preserved and that the conclusions drawn can be considered valid despite minor indications of publication bias.

Qualitative Analysis

Table 8. Thematic Analysis of Factors Influencing the Success of Technology-Assisted Therapy (TAT)

Theme No.	Theme Description	Observation / Note
1	Platform Accessibility and Flexibility	Consistently cited across all TAT modalities and subgroups
2	Patient Engagement and Motivation	Higher engagement is associated with better therapy outcomes
3	Quality of Therapeutic Relationship in Digital Context	Strong therapeutic alliance enhances effectiveness
4	Personalization of Therapy Experience	Tailored interventions improve adherence and clinical outcomes

Note: *Themes were identified through a thematic synthesis across all studies, reflecting consistent qualitative patterns that influence TAT effectiveness.*

As shown in the eighth table above, the qualitative analysis of 47 studies on Technology-Assisted Therapy (TAT) for war-related trauma underscores that intervention success is profoundly influenced by four primary themes consistently observed across modalities and participant subgroups: platform accessibility and flexibility, patient engagement and motivation, the quality of the therapeutic relationship within digital contexts, and the personalization of the therapeutic experience. Each of these themes is consistently associated with increased participant adherence and clinical effectiveness, emphasizing that contextual and individual factors interact synergistically to maximize TAT outcomes and highlighting the importance of adaptive and personalized intervention design for populations experiencing heterogeneous war-related trauma.

As a closing remark, the synthesis of the 47 studies confirms that Technology-Assisted Therapy (TAT) is effective in addressing war trauma, with variations in effectiveness influenced by intervention modality, duration, therapist support, and the level of content personalization. Virtual Reality Exposure Therapy (VRET) demonstrates the highest effectiveness, particularly when combined with adequate therapeutic support and individualized content adjustments, affirming that an adaptive, participant-centered intervention design constitutes a strong empirical foundation for developing optimized TAT protocols that are responsive to the complexities of war-related trauma.

Discussion

This meta-synthesis produced a series of substantive findings that deepen the understanding of the effectiveness of Technology-Assisted Therapy in the treatment of war-related trauma, while also providing empirical validation for the proposed hypotheses. The

significant overall effect size of d = 0.78 confirms that TAT is not only comparable to but, in many contexts, exceeds the effectiveness of conventional therapy, particularly among populations of survivors of armed conflict. This finding strengthens the report by Tng et al. (2024), who identified an effect size of d = 0.72 for digital interventions in general PTSD. However, the present meta-synthesis demonstrates that the characteristics of war-related trauma, which tend to be more chronic and complex, actually show a stronger therapeutic response when mediated by appropriately designed technology. Accordingly, TAT should not be viewed merely as a pragmatic alternative arising from limited access to services, but rather as a therapeutic approach with intrinsic potential to facilitate trauma processing.

Among the modalities analyzed, Virtual Reality Exposure Therapy emerged as the most effective, with a d = 0.85, consistent with the meta-analysis by Eshuis et al. (2021). The superiority of VRET can be understood through its capacity to create controlled, gradual, and safe trauma exposure, thereby enabling habituation and the reconstruction of traumatic memory to proceed more systematically. A high level of immersivity plays a critical role in activating the emotional responses required for deep trauma processing, as demonstrated by Ehuis et al. (2021). However, this meta-synthesis extends previous findings by identifying the personalization of VRET content as a significant determinant of intervention effectiveness, as reflected in a β coefficient of 0.29. This indicates that the success of VRET is not determined solely by technological sophistication, but by the extent to which virtual stimuli are tailored to the trauma narrative and psychological characteristics of each survivor.

The second hypothesis, which proposed the superiority of hybrid interventions over single-platform approaches, was also strongly confirmed. The effect size of d = 0.89 for hybrid interventions, compared with d = 0.67 for single-platform interventions, indicates that integrating multiple digital modalities enables a more holistic recovery approach. This finding advances the work of Wu et al. (2025), which previously highlighted the effectiveness of single platforms, by demonstrating that cross-modality integration can better accommodate the diversity of clinical needs and individual patient preferences. In the context of war-related trauma, recovery rarely proceeds linearly, so approaches that combine exposure, emotion regulation, and psychoeducational support across multiple digital channels are more adaptive and responsive.

Therapist support was shown to function as a significant moderator (β = 0.28), in line with the third hypothesis and reinforcing the findings of Stefanopoulou et al. (2020). Further analysis, however, revealed that the relationship between therapist support and intervention effectiveness is not linear. The highest effectiveness was achieved with moderate guidance, in

which the therapist serves as a facilitator, maintaining therapeutic direction without diminishing patient autonomy. This nuance carries important implications for the development of hybrid care models, as it suggests that the optimal use of therapist resources does not require intensifying clinical presence, but rather involves strategically and contextually adjusting professional roles.

Finally, technological characteristics were also shown to significantly influence therapeutic outcomes, as formulated in the fourth hypothesis. Immersivity ($\beta = 0.31$) and interactivity ($\beta = 0.26$) contributed substantially to intervention effectiveness. These findings extend Isa's (2024) work by identifying a threshold beyond which increasing technological complexity yields diminishing returns. In other words, technology that becomes overly complex without a clear therapeutic rationale does not necessarily enhance effectiveness and may even divert attention from core clinical processes.

From a theoretical perspective, these results make a significant contribution to the development of trauma theory and digital psychotherapy. The findings support the framework of processing therapy, which emphasizes the importance of emotional engagement in trauma recovery, while also extending it by positioning technology as an active mediator within this process. The effectiveness of hybrid interventions challenges earlier theoretical approaches that tended to dichotomize therapeutic modalities and encourages the formulation of more integrative models that better reflect contemporary clinical realities. Based on these findings, a new theoretical model can be articulated that incorporates technology engagement as a catalyst for trauma processing, the formation of therapeutic alliance within digital ecosystems, and personalized intervention pathways aligned with individual response patterns.

From a practical perspective, this meta-synthesis provides concrete guidance for developing TAT protocols. An optimal intervention duration in the range of 12–16 weeks with sessions lasting 60–90 minutes, the integration of at least two digital modalities, the implementation of real-time monitoring systems for intervention adjustment, and the development of specific security protocols for sensitive trauma data emerge as critical components. The findings also underscore the importance of therapist training focused on digital competencies specific to war-related trauma, the optimization of therapeutic alliance in online media, and the capacity to personalize interventions using data-driven approaches. At the system level, the development of scalable technological infrastructure, the integration of AI-based outcome-monitoring systems, and the implementation of risk management and crisis

intervention protocols are essential prerequisites for the successful large-scale implementation of TAT.

Several limitations should nevertheless be considered when interpreting these results. Methodological heterogeneity across studies, variation in the operational definitions of outcome measures, differences in TAT implementation protocols, and limited standardization of digital engagement measurement may affect the consistency of findings. In addition, the underrepresentation of war refugee populations and the limited number of studies conducted in active conflict regions constrain the generalizability of the results, compounded by the potential for bias in the reporting of negative outcomes. Technological and infrastructural factors, including variability in implementation quality and limited internet access in certain regions, also represent constraints that cannot be ignored.

In light of these findings and limitations, future research should be directed toward the development of standardized protocols for TAT implementation, long-term longitudinal studies with durations exceeding two years, and in-depth investigation of the specific mechanisms of change within TAT. From a technological perspective, the evaluation of emerging technologies such as augmented reality and AI therapists, the development of machine learning-based personalization algorithms, and feasibility studies in low-resource settings constitute important research priorities. Research involving specific populations, including child victims of war, cross-cultural comparisons, and complex trauma, is also needed to broaden the empirical scope.

Overall, this meta-synthesis confirms the significant potential of Technology-Assisted Therapy in the treatment of war-related trauma, not only as a response to limited access to mental health services, but as a therapeutic approach that opens new possibilities for more personalized, adaptive, and effective interventions. The integration of technology into trauma therapy, when designed and implemented with critical rigor, has the potential to reshape the landscape of trauma psychotherapy for populations affected by armed conflict.

4. CONCLUSION

This meta-synthesis presents robust empirical evidence regarding the effectiveness of Technology-Assisted Therapy in the treatment of war-related trauma through a comprehensive analysis of 47 studies involving a total of 6,842 participants. The principal findings indicate a substantial overall effect size of d = 0.78, which confirms that TAT constitutes an effective intervention for populations of armed conflict survivors. Among the various modalities examined, Virtual Reality Exposure Therapy demonstrated the highest effectiveness, with a d

value of 0.85. At the same time, approaches integrating multiple platforms yielded more optimal outcomes, with an effect size of d = 0.89, compared with single-platform approaches. This pattern of findings indicates that the effectiveness of TAT is not determined solely by the presence of technology itself, but rather by the configuration of the intervention, the degree of personalization, and the strategic integration across modalities.

The primary contribution of this study lies in its comprehensive mapping of the factors that influence the effectiveness of TAT within the context of war trauma. This area has remained fragmented within the existing literature. In contrast to previous meta-analyses that tended to focus on a single therapeutic modality, this study reveals the superiority of hybrid approaches. It highlights the crucial role of personalized intervention and optimal therapist support. The identification of effective thresholds for technological characteristics and the intensity of clinical support provides practical guidance that has not previously been available in a systematic form, while also strengthening the foundation for clinical decision-making and the design of technology-based mental health services.

The novelty of this research is reflected in the development of an integrated theoretical model that brings together technological dimensions, therapeutic alliance, and trauma processing within a coherent conceptual framework. This model offers a new perspective for understanding mechanisms of change in digital trauma therapy and moves beyond partial approaches that separate technological and clinical aspects. In doing so, this study contributes to a paradigm shift from viewing technology merely as an auxiliary tool to understanding it as an active mediator within the therapeutic process.

Based on these findings, the practical implications include the need to implement standardized TAT protocols with a duration of 12–16 weeks, the integration of at least two digital modalities with a high level of personalization, the development of real-time outcome monitoring systems, and the enhancement of digital competencies among trauma practitioners. At the policy level, it is necessary to establish specific guidelines for implementing TAT within mental health systems, allocate resources to strengthen digital infrastructure in conflict-affected regions, standardize the protection of sensitive trauma data, and integrate TAT into health insurance schemes. From the perspective of future research, priority agendas include long-term longitudinal studies, the development of AI-based algorithms for intervention personalization, evaluation in special populations, and cross-cultural validation.

Overall, Technology-Assisted Therapy demonstrates transformative potential in the treatment of war-related trauma by offering solutions that are scalable, adaptive, and effective in addressing global mental health challenges. The success of its implementation depends on carefully integrating technological innovation, sound therapeutic principles, and a deep understanding of survivors' specific needs, so that technology genuinely contributes to holistic, evidence-based trauma recovery.

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