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Post-traumatic growth amongst UK armed forces personnel who were deployed to Afghanistan and the role of combat injury, mental health and pain: the ADVANCE cohort study

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Abstract

Background. Post-traumatic growth (PTG) is a positive psychological consequence of trauma. The aims of this study were to investigate whether combat injury was associated with deployment-related PTG in a cohort of UK military personnel who were deployed to Afghanistan, and whether post-traumatic stress disorder (PTSD), depression and pain mediate this relationship.
Methods. 521 physically injured ($n = 138$ amputation; $n = 383$ non-amputation injury) and 514 frequency-matched uninjured personnel completed questionnaires including the deployment-related Post-Traumatic Growth Inventory (DPTGI). DPTGI scores were categorised into tertiles of: no/low (score 0–20), moderate (score 21–34) or a large (35–63) degree of deployment-related PTG. Analysis was completed using generalised structural equation modelling.
Results. A large degree of PTG was reported by 28.0% ($n = 140$) of the uninjured group, 36.9% ($n = 196$) of the overall injured group, 45.4% ($n = 62$) of amputee and 34.1% ($n = 134$) of the non-amputee injured subgroups. Combat injury had a direct effect on reporting a large degree of PTG [Relative risk ratio (RRR) 1.59 (95% confidence interval (CI) 1.17–2.17)] compared to sustaining no injury. Amputation injuries also had a significant direct effect [RRR 2.18 (95% CI 1.24–3.75)], but non-amputation injuries did not [RRR 1.35 (95% CI 0.92–1.93)]. PTSD, depression and pain partially mediate this relationship, though mediation differed depending on the injury subtype. PTSD had a curvilinear relationship with PTG, whilst depression had a negative association and pain had a positive association.
Conclusions. Combat injury, in particular injury resulting in traumatic amputation, is associated with reporting a large degree of PTG.

Introduction

Armed Forces personnel who were deployed to the Middle East during the conflicts in Iraq and Afghanistan have been the subject of much research over the past two decades. While the negative psychological consequences of such deployments have been well researched (Fear et al., 2010; Hotopf et al., 2006; Stevelink et al., 2018), the research on positive psychological outcomes has been limited. Post-traumatic growth (PTG) is one such potential positive outcome, being the experience of beneficial psychological change following exposure to trauma (Tedeschi & Calhoun, 1996). To the authors' best knowledge, only two papers have investigated PTG in the UK Armed Forces. The first establishes that PTG can be elicited during therapy for PTSD (Murphy, Palmer, Lock, & Busuttil, 2017). The second paper investigates PTG amongst Iraq/Afghanistan deployed UK personnel and establishes that those who reported deployment-related PTG also reported better overall health, better mental health (excluding PTSD) and deployment-related factors such as the belief that they may be seriously injured or killed or a reporting a greater number of combat experiences (Dyball, Taylor-Beirne, Greenberg, Stevelink, & Fear, 2022b), though there are mixed results on the effect of combat experiences in the US literature (Jacobson et al., 2021; Mitchell, Gallaway, Millikan, & Bell, 2013). The UK analysis (Dyball et al., 2022b) investigated overall health, but not physical injuries received during deployment and their potential effect on PTG. Data on the US military have found support for the experience of PTG amongst combat-injured amputees (Benetato, 2011).

It is well recognised that PTG can occur after both physical or psychological trauma (Wu et al., 2019), and it has been shown to be associated with better mental health outcomes such as lower rates of depressive disorders in longitudinal studies of those with serious medical conditions, (Barskova & Oesterreich, 2009). One significant exception to this is PTSD, which has an inverted 'u'-shaped (curvilinear) relationship with PTG (Shakespeare-Finch & Lurie-Beck, 2014), whereby as PTSD symptoms increase, so does PTG, until a threshold is met, at which point as PTSD symptoms increase, PTG decreases. Health-related quality of life, such as levels of pain/discomfort, have also been found to be better (e.g. lower levels of pain/discomfort) amongst those who experience greater PTG (Barskova & Oesterreich, 2009). Sustaining a physical combat injury is associated with greater rates of PTSD, depression and pain in both US and UK Armed Forces (Dyball et al., 2022a; Ramchand, Rudavsky, Grant, Tanielian, & Jaycox, 2015; Van Den Kerkhof, Carley, Hopman, Ross-White, & Harrison, 2014), but is also associated with high rates of PTG (Benetato, 2011; Mark, Stevelink, Choi, & Fear, 2018). No known studies have investigated whether PTSD, depression and pain mediate the relationship between physical combat injury and PTG.

The ADVANCE study follows a cohort of UK Armed Forces personnel who sustained a physical combat injury in Afghanistan and an uninjured comparison group (Bennett et al., 2020). Its aim is to investigate the impact of sustaining a physical combat injury on long-term health. We have recently reported that overall, those who were injured were more likely to report poor mental health outcomes including PTSD, depression, anxiety, and mental health multimorbidity, however this varied by the type of injury sustained (Dyball et al., 2022a). Those with non-amputation injuries were more likely to report poor mental health outcomes compared to the uninjured comparison group. However, those with amputation-related injuries were no more likely to report poor mental health outcomes than the uninjured group and were less likely to report poor mental health outcomes when compared to the non-amputation-related injury group.

In this paper, we aim to: (1) report on PTG experienced as a result of military deployments to Iraq/Afghanistan in a cohort of physically injured and a frequency-matched uninjured comparison group of UK Armed Forces personnel (the ADVANCE study cohort), (2) examine whether those with amputation injuries and those with non-amputation injuries differ in the likelihood of reporting deployment-related PTG compared to the uninjured group and (3) examine whether differences in PTG are mediated by pain, PTSD symptoms and depression.

Methods

Participants/procedure

Injured participants were recruited from a sample of physically combat-injured UK Armed Forces personnel, provided by the Ministry of Defence (MoD) Defence Statistics (Health) (Bennett et al., 2020). Between 2015 and 2020, 579 physically injured UK Armed Forces men who were deployed to Afghanistan and were aero-medically evacuated to a UK hospital were recruited into the ADVANCE study. A further 566 UK Armed Forces personnel, who were recruited from a recruitment sample frequency-matched to the injured group based on sex, age, rank, role on deployment, regiment and period of deployment (deployed to Afghanistan during the same time period, e.g. HERRICK 4, April 2006–September 2006). Participants completed a study day (hereby defined as the ADVANCE assessment) consisting of a comprehensive health investigation, a research nurse-led clinical interview and a self-completed questionnaire. Response rates adjusted for deaths and participants with no contact details were 59.6% for the injured group and 56.3% for the uninjured comparison group (Dyball et al., 2022a). A measure of PTG was introduced to the ADVANCE cohort in 2018. From this point, participants completed the questionnaire as part of their clinical assessments. All participants who attended their ADVANCE study appointment prior to this date were invited to complete the questionnaire either online or via post.

Materials

PTG

The Post-Traumatic Growth Inventory is a 21-item measure of PTG (Tedeschi & Calhoun, 1996), of which a deployment-related version (DPTGI) was administered to our participants (Dyball et al., 2022b). The stem question for the DPTGI was 'Please read each statement and tell us whether you have changed for the better as a result of ALL your deployments to Iraq/Afghanistan since 2002'. Scores range from 0 to 63, with higher scores indicating greater PTG.

Combat injury

Initial information on combat injury was collected from MoD medical records, with additional details provided by self-report in the clinical interview, including the type of injury (e.g. amputation). Amputees were defined as any amputation above/below/through the knee or above/below the elbow. Participants who experienced a partial amputation only (e.g. digit, partial hand, partial foot) were included in the non-amputation injury subgroup.

Depression

Depression was measured using the Patient Health Questionnaire-9 (PHQ), a nine-item measure of depression. Probable depressive disorder was defined as a score of $\geqslant$10 (scores range from 0 to 27) (Kroenke, Spitzer, & Williams, 2001).

Pain

Pain was evaluated using the EQ-5D-5L quality of life measure, a six-item self-report questionnaire that identifies mobility, self-care, usual activities, pain/discomfort, mental health and overall health (Herdman et al., 2011). The pain/discomfort subscale score was used and a score of $\geqslant$2 was used to indicate current moderate-extreme pain (scores range from 0 to 4). This subscale has been established to have a moderate-strong correlation with other pain measures (Feng, Kohlmann, Janssen, & Buchholz, 2021).

PTSD

PTSD was measured using the PTSD Check List (PCL-C), a 17-item measure of PTSD according to the DSM-IV-related symptoms over the past month. Probable PTSD was defined as a score of ⩾50 (scores range from 17 to 85) (Blanchard, Jones-Alexander, Buckley, & Forneris, 1996).

Time since deployment

Time since deployment was measured as the number of years between their age at sampled deployment/injury to age at completion of the DPTGI measure.

Data analysis

Data analysis was performed using STATA version 17.0. Cronbach's alpha was used to assess the internal consistency of the DPTGI. Scores of the DPTGI were converted to tertiles based on the full sample, creating three categories: No/a low degree of PTG (scores 0–20), a moderate degree of PTG (scores 21–34) and a large degree of PTG (35–63). Rank was coded into three categories as an indicator of socioeconomic status; NATO OR2-OR4 (junior non-commissioned officer rank), NATO OR5-OR9 (senior non-commissioned officer rank) and NATO OF1-OF6 (commisionned officer rank) (Yoong, Miles, McKinney, Smith, & Spencer, 1999).

Socioeconomic status/rank (Dyball et al., 2022b), age (Dyball et al., 2022b) and time since sampled deployment (Morgan & Desmarais, 2017) were controlled for due to the strong evidence base for these associations with PTG. The injured group was investigated as a whole, and then split into the two subgroups from which the initial sampling was based; those with amputation injuries and those with non-amputation injuries (Bennett et al., 2020).

Weighted percentages are presented along with unweighted cell counts based on sampling and response characteristics of those recruited into the ADVANCE study. Sampling weights were applied to the injured group, which accounted for the under-sampling of those with less-severe injuries defined by NOTICAS causality rating (Bennett et al., 2020). Response weights were calculated based on age, rank and branch of service at the time of sampling due to more officers, royal marines and older (by approximately one year) participants being represented in those that took part in the study. Response weights and sampling weights were multiplied together and applied to descriptive tables using the 'svy' command in STATA. Response bias to completing the DPTGI between the uninjured, injured, amputation injury subgroup and non-amputation injury subgroup was assessed via χ^2.

Due to the known curvilinear relationship between PTSD and PTG (Shakespeare-Finch & Lurie-Beck, 2014), the PCL-C score was centred (PCL-C score-mean score) and a second variable (centred PCL-C score^2) was included as confirmed by linear regression and subsequent likelihood ratio test. Participants with >3 items missing from the DPTGI were excluded ($n = 2$). 400 participants did not complete one item of the DPTGI due to an administration error. Missing data for participants with ⩽3 items missing on an item-level on the DPTGI were imputed using two-way imputation ($n = 434$) (Van Ginkel, Van der Ark, Sijtsma, & Vermunt, 2007). Multiple imputations were considered, however missing data on any other variable of interest were low (<1%; $n = 8$), and so was dealt with using casewise deletion. Generalised Structural Equation Modelling (GSEM) models using imputed and unimputed scores were compared and no notable differences between the GSEM models were observed (available from the authors).

GSEM multinomial models were used in three steps. The first model that assessed the relationship between PTSD, PTSD^2, depression and pain with a moderate and a large degree of PTG compared to no/a low degree of PTG. The second investigated whether, when compared to the uninjured group, the overall combat injured group, the amputation injury subgroup and the non-amputation injury subgroup were associated with a moderate or a large degree of PTG compared to no/a low degree of PTG (unmediated models). The third step was to introduce variables which assessed whether PTSD, PTSD^2, depression and pain mediated these relationships (mediated models). All continuous variables were standardised prior to input into the model using the 'zval' command. Coefficients are reported in the GSEM figures, and exponentiated coefficients [Relative risk ratios (RRR)] are reported in tables and text for direct and indirect effects of injury status on PTG. Bias-corrected confidence intervals are presented and were bootstrapped using 1000 reps. Direct and indirect effects were estimated using non-linear combinations of estimators (the 'nlcom' command). Due to inconsistent mediation, total effects were not reported.

Results

90.4% ($n = 1035/1145$) of the ADVANCE study participants completed the DPTGI. 90.0% ($n = 521/579$) of the overall injured group, 85.0% ($n = 138/162$) of the amputation subgroup and 91.6% ($n = 383/418$) of the non-amputation injury subgroup completed the DPTGI. 90.8% ($n = 514/566$) of the uninjured group completed the DPTGI. No significant differences were noted between the rates of injured amputees, injured non-amputees and uninjured participants who completed the DPTGI, (χ^2 (df = 3) 1.77, $p = 0.17$). 27.0% ($n = 279$) of the sample completed the DPTGI ⩾12 months after their ADVANCE assessment.

Table 1 describes the sociodemographic, deployment-related factors and frequency of the DPTGI tertiles by injury status. Cronbach's alpha for the DPTGI was 0.94, suggesting excellent internal consistency. The overall median score on the DPGTI was 28 (IQR 16, 39). Amongst the uninjured group, the median DPTGI score was 26 (IQR 15, 36) and amongst the injured group the median DPTGI score was 30 (IQR 17, 42). The amputation subgroup median score was 33 (IQR 21, 46) and the non-amputation-related injury subgroup median score was 28 (IQR 16, 41). The uninjured group were approximately one year older on average, had a greater proportion of higher ranks, deployed more recently to their sampled deployment era by approximately six months on average, reported lower PTSD and depression scores, reported less pain and had a lower proportion of low scores on the DPTGI compared to the injured group.

Figure 1 shows the GSEM applied to the whole cohort, with a moderate or large degree of PTG (both compared to no/a low degree of PTG) as the dependent variable and PTSD symptoms, PTSD symptoms^2, depression symptoms and reporting moderate-extreme pain at ADVANCE assessment as independent variables after adjusting for confounders. PTSD symptoms had moderate-strong positive associations with reporting both a moderate and large degree of PTG compared to reporting no/a low degree of PTG. PTSD symptoms^2 and depression symptoms had moderate-very strong negative associations with reporting a

Table 1. Sociodemographic, deployment and post-traumatic growth characteristics by injury status, *n* (%) and median (IQR)

	Total group (*n* = 1035)	Uninjured group (*n* = 514)	Injured group: Overall (*n* = 521)	Injured group: Amputation subgroup (*n* = 138)	Injured group: Non-amputation injury subgroup (*n* = 383)
Median age at ADVANCE assessment (IQR)	34 (30, 37)	34 (31, 37)	33 (30, 37)	32 (30, 36)	34 (30, 38)
Ethnicity *n* (%)					
White Caucasian	939 (90.5)	465 (90.1)	474 (90.8)	127 (92.0)	347 (90.4)
All Other Ethnic Minorities	96 (9.5)	49 (9.9)	47 (9.2)	11 (8.0)	36 (9.6)
Rank at sampling *n* (%)					
Junior non-comissioned officer rank	670 (70.8)	302 (65.1)	368 (75.7)	111 (84.7)	257 (72.8)
Senior non-commissioned officer *rank*	236 (21.4)	138 (25.7)	98 (17.7)	17 (10.9)	81 (20.0)
Commissioned *Officer rank*	129 (7.8)	74 (9.2)	55 (6.6)	10 (4.4)	45 (7.2)
Median number of deployments to Iraq/ Afghanistan (IQR)	2 (1, 3)	2 (2, 3)	2 (1, 3)	2 (1, 3)	2 (1, 3)
Median years between sampling deployment and DPTGI assessment (IQR)	9.1 (8.0, 10.3)	8.8 (7.8, 10.0)	9.3 (8.2, 10.6)	9.1 (7.9, 9.9)	9.5 (8.3, 10.8)
Median PCL score at ADVANCE assessment (IQR)	26 (19.5, 37)	23 (18, 32)	29 (21, 41)	25 (20, 33)	30 (22, 44)
Median PHQ9 score at ADVANCE assessment (IQR)	3 (1, 8)	2 (0, 7)	4 (1, 9)	4 (1, 7)	4 (2, 9)
Moderate/severe/extreme pain or discomfort at ADVANCE assessment *n* (%)	184 (18.7)	60 (12.3)	124 (24.0)	27 (20.1)	97 (25.3)
No/a low degree of PTG (DPTGI 0–20)	360 (34.4)	197 (37.1)	163 (32.1)	33 (24.4)	130 (34.6)
Moderate degree of PTG (DPTGI 21–34)	339 (32.8)	177 (34.9)	162 (31.0)	43 (30.2)	119 (31.3)
Large degree of PTG (DPTGI 35–63)	336 (32.8)	140 (28.0)	196 (36.9)	62 (45.4)	134 (34.1)

Acronyms: DPTGI, Deployment-related Post-Traumatic Growth Inventory; IQR, Inter-Quartile Range; MSPSS, Multidimensional Scale of Perceived Social Support; PHQ9, Patient Health Questionnaire; PTG, Post-traumatic growth; PTSD, Post-traumatic stress disorder; PCL, PTSD Check List.
Weighted percentages are presented alongside unweighted cell counts.

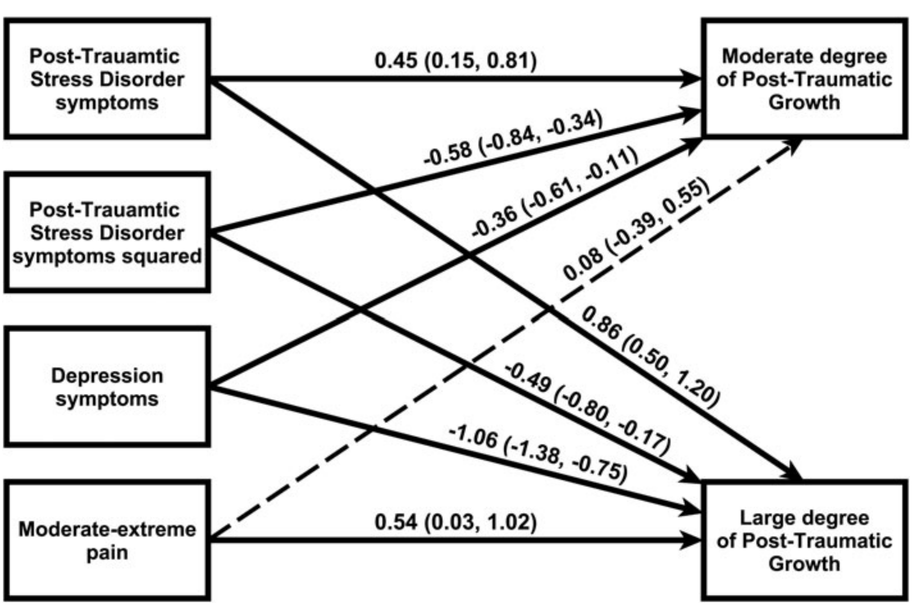

Fig. 1. Generalised Structural Equation Model investigating the effect of PTSD, depression and pain on a moderate/large degree of PTG in the whole cohort. Model adjusted for age at ADVANCE assessment, rank at sampling and time since sampled deployment/ injury to completing the DPTGI. Standardised coefficients and 95% confidence intervals shown. Confidence intervals that suggest non-significant associations are denoted as dotted lines.

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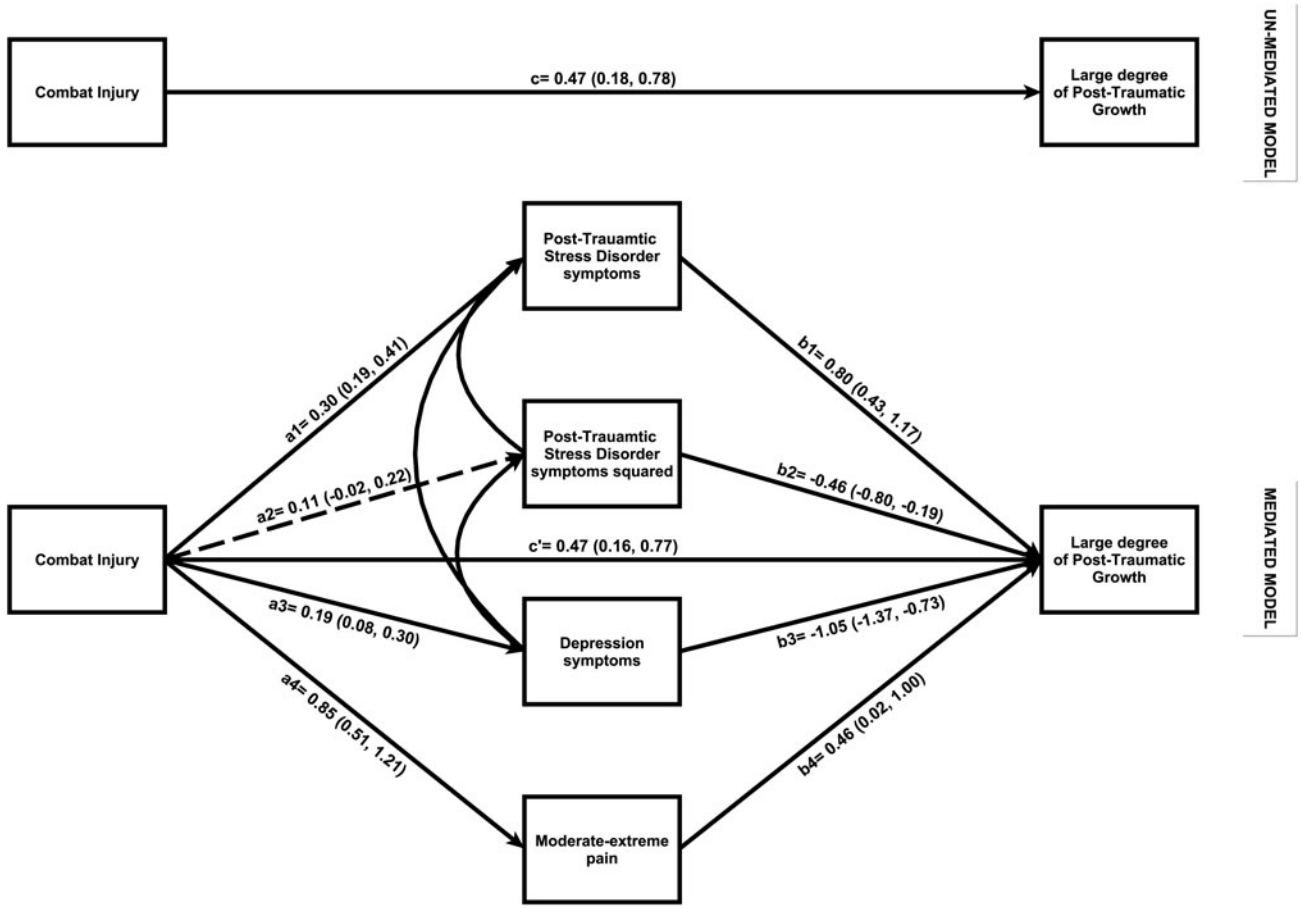

Fig. 2. Generalised Structural Equation Model assessing the relationship between combat injured group (*v.* uninjured group) and reporting a large degree of PTG, mediated by PTSD symptoms, PTSD symptoms^2, depression and pain. Model adjusted for age at ADVANCE assessment, rank at sampling and time since sampled deployment/injury to completing the DPTGI. Standardised coefficients and 95% confidence intervals shown. Confidence intervals that suggest non-significant associations are denoted as dotted lines.

moderate degree and a large degree of PTG compared to no/a low degree of PTG. Current moderate-extreme pain had no/very minimal associations with reporting a moderate degree of PTG, but had a moderate positive association with a large degree of PTG compared to no/a low degree of PTG.

Figures 2–4 show the GSEM investigating the association between combat injury, amputation injury and non-amputation injury with reporting a large degree of PTG, mediated by PTSD, depression and pain after adjusting for confounders. Whilst PTSD symptoms, PTSD symptoms^2, depression and pain continued to be associated with reporting a large degree of PTG in the combat injury model (Fig. 2), current moderate-extreme pain was no longer associated in the amputation (Fig. 3) and non-amputation injury (Fig. 4) subgroups. Similar but smaller effects were noted in the GSEM models for a moderate degree of PTG (online Supplementary materials 1).

Table 2 reports on the direct and indirect effects of the GSEM models reported in Figs 2–4. In the overall injury group, after adjusting for confounders, sustaining an injury had a direct effect on reporting a large degree of PTG compared to no/a low degree of PTG [RRR 1.59 (95% CI 1.17–2.17)] and also an indirect effect through PTSD symptoms, depression and pain. No indirect effect was noted for PTSD symptoms^2. Sustaining an amputation injury had a direct effect on reporting a large degree of PTG [RRR 2.37 (95% CI 1.22–3.51)], but no indirect effects were noted for any of the mediators. Sustaining a non-amputation injury did not have a direct effect on reporting a large degree of PTG [RRR 1.35 (95% CI 0.92–1.93)], but did have indirect effects through PTSD symptoms, PTSD symptoms^2 and depression. No indirect effect was noted for pain.

Discussion

In this study, we set out to report on PTG in a cohort of injured and uninjured UK Armed Forces personnel who were deployed to Afghanistan and to understand the effect of sustaining a combat injury on subsequent PTG. After adjustment for confounders, the direct effect of sustaining a combat injury *v.* being uninjured was associated with a 59% increased relative risk of reporting a large degree of PTG compared to reporting no/a low degree PTG. The direct effect of sustaining an amputation injury *v.* being uninjured was associated with a 118% increased relative risk of reporting a large degree of PTG. In contrast, the direct effect of sustaining a non-amputation injury *v.* being uninjured was not associated with a large degree of PTG. While our models suggested that PTSD, depression and pain partially mediated the relationship between combat injury and a large degree of PTG, heterogeneity was noted between the indirect effects of different subtypes of injury (amputation and non-amputation injuries) on a large degree of PTG.

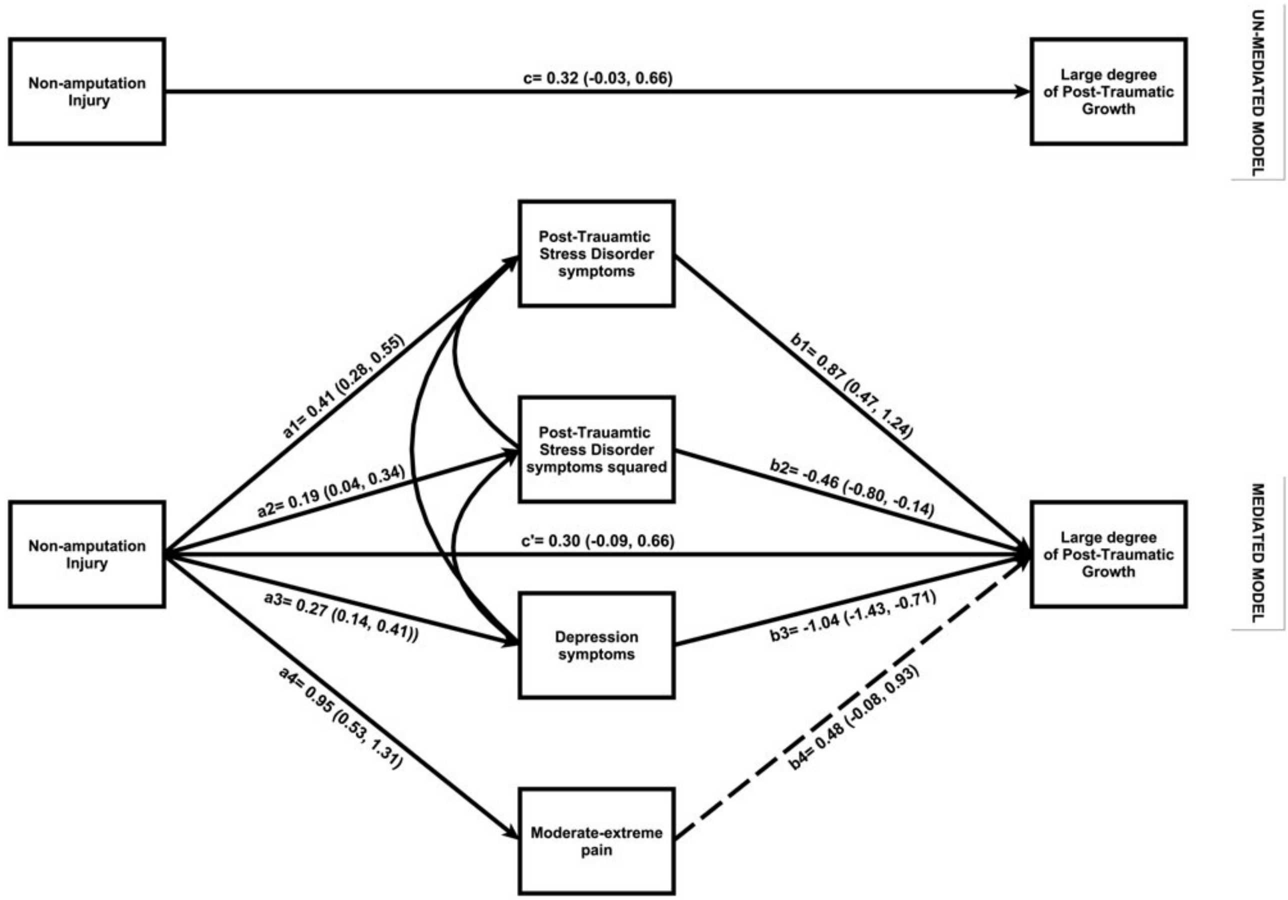

Fig. 3. Generalised Structural Equation Model assessing the relationship between amputation injured subgroup (*v.* uninjured group) and reporting a large degree of PTG, mediated by PTSD symptoms, PTSD symptoms^2, depression and pain. Model adjusted for age at ADVANCE assessment, rank at sampling and time since sampled deployment/injury to completing the DPTGI. Standardised coefficients and 95% confidence intervals shown. Confidence intervals that suggest non-significant associations are denoted as dotted lines.

The ADVANCE study cohort has reported that those who sustained a non-amputation-related injury reported significantly greater rates of depression, anxiety, PTSD and multimorbidity compared to an uninjured comparison group (Dyball et al., 2022a). Those with an amputation injury reported no significant differences in rates of poor mental health outcomes compared to the uninjured comparison group, and significantly less than their peers with non-amputation-related injuries. In this analysis, we find those with an amputation injury were more likely to report a large degree of PTG and those with a non-amputation injury were no more likely to report a large degree of PTG compared to the uninjured group. A possible explanation for this disparity is that while both the amputation and non-amputation injury groups were both exposed to similar traumas (combat injury) and subsequent Defence Medical Service rehabilitation, the amputee group may have had increased access to other therapeutic or charitable services, which allowed them to facilitate more PTG (Murphy et al., 2017). It is of particular note that the association between combat injury and reporting a large degree of PTG was only partially mediated by factors such as PTSD and depression. There is a suggestion therefore that PTG is more than just the absence of mental illness, though further work is needed to establish the validity and clinical meaningfulness of PTG (Frazier, Coyne, & Tennen, 2014; Jacobson et al., 2021). A continued longitudinal investigation of this cohort might help elucidate whether these beneficial psychological outcomes are maintained over the long term, and whether they could be considered as a protective factor against poor mental health outcomes.

Much of the literature on PTG in military personnel who have sustained an amputation injury has focussed on US samples (Mark et al., 2018). Most suggest that amputees experience a moderate-large amount of PTG following their injury, though none of those research studies has referenced a suitable uninjured comparison group. The DPTGI has also been administered in a representative cohort study investigating the wellbeing of UK military personnel who were deployed to Iraq/Afghanistan (Dyball et al., 2022b). In that cohort, the median score on the DPTGI was 13 (IQR 5, 24); factors such as sex, combat role, number of combat experiences, belief of being at serious risk of injury or death, reservist status, and better general health were associated with a moderate-large degree of PTG. In the ADVANCE study cohort, the median DPTGI score was far higher [28 (IQR 16, 39)]. There are a number of possible explanations for this difference. Since the belief of being at serious risk of injury/death has previously been shown to be associated with PTG (Dyball et al., 2022b; Ramchand et al., 2015), it is unsurprising that the ADVANCE cohort would experience more PTG since approximately half of the cohort sustained a serious combat injury. Additionally, the ADVANCE cohort is primarily made up of

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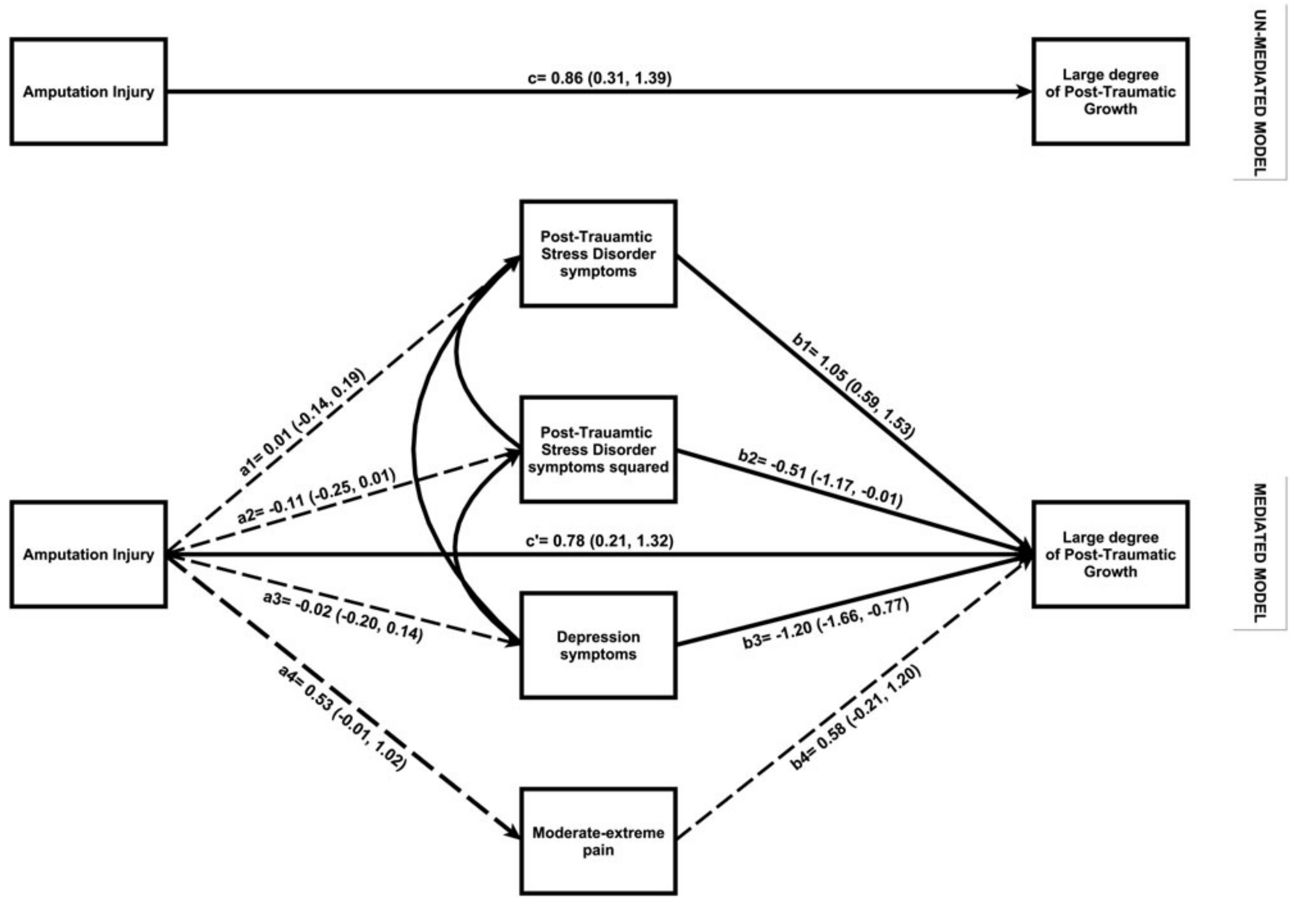

Fig. 4. Generalised Structural Equation Model assessing the relationship between non-amputation injured subgroup (*v.* uninjured group) and reporting a large degree of PTG, mediated by PTSD symptoms, PTSD symptoms^2, depression and pain. Model adjusted for age at ADVANCE assessment, rank at sampling and time since sampled deployment/injury to completing the DPTGI. Standardised coefficients and 95% confidence intervals shown. Confidence intervals that suggest non-significant associations are denoted as dotted lines.

combat personnel who likely had high combat exposure. Services such as the RAF and the Royal Navy are less represented in the ADVANCE cohort, and such services would have different deployment and combat experiences compared to the Army or Royal Marines. Interpretation of results from either cohort should be considered with this in mind.

There are clinical implications of our findings, which suggest that the experience of deployment-related PTG may be more than just the absence of mental illness. The Medical Force Protection, the Armed Forces initiative to promote and maintain a healthy fighting force, might benefit from focussing not just on lowering the risk of poor mental health outcomes, but also nurturing positive mental well-being. Further to this, understanding why amputees appear to report less poor mental health outcomes and increased positive mental health outcomes compared to injured non-amputees is an important future avenue of research. PTG is associated with better mental and physical health, as well as lifestyle factors such as increased use of physical exercise and lower use of alcohol or smoking (Barskova & Oesterreich, 2009), meaning that interventions that could elicit PTG might produce favourable psychological and physical health benefits (Murphy et al., 2017). Increased efforts should be made to make these services accessible to those who require them, with our study suggesting that those who experienced non-amputation injuries during deployment being one such group who might benefit.

To the authors' best knowledge, this study is the first to examine mental health and pain mediation pathways between combat injury and PTG. Current moderate-extreme pain was positively associated with a large degree of PTG when investigating the whole cohort and mediation analysis showed that the relationship between combat injury and PTG was partially mediated by pain. One possible explanation for this is through rumination. Rumination on the trauma is a necessary component of PTG (Mark et al., 2018; Morgan, Desmarais, Mitchell, & Simons-Rudolph, 2017) and has also been associated with increased pain intensity and pain catastrophising (Sansone & Sansone, 2012). It is possible that in our cohort, pain causes rumination on the participants' deployment experiences/injury, which could facilitate PTG. Whilst the general literature on PTG in those with a serious medical condition suggests that greater PTG is associated with lower pain (Barskova & Oesterreich, 2009), the evidence for this relationship varied depending on the nature of the study (e.g. cross-sectional *v.* longitudinal) or sample under investigation (e.g. type of serious medical issue). Given the known relationship between pain and other factors of general well-being and functioning (Burke, Mathias, & Denson, 2015), further investigation into pain and PTG amongst injured UK military personnel is warranted.

Strengths of the study include the use of a frequency matched uninjured group, matched to the injured group on important

Table 2. Direct and indirect effects of combat injury on PTG through mediating factors of PTSD, PTSD^2, depression and pain

Injury status	Mediation status	Figure reference	Moderate degree of post-traumatic growth RRR (95% CI)	Large degree of post-traumatic growth RRR (95% CI)
Overall injury group (*v.* uninjured group)	Direct (unmediated)	Figure 2: c	1.07 (0.80–1.48)	1.59 (1.20–2.19)
	Direct (mediated)	Figure 2: c'	1.09 (0.78–1.53)	1.59 (1.17–2.17)
	Indirect: post-traumatic stress disorder symptoms[1]	Figure 2: a1*b1	1.14 (1.04–1.31)	1.28 (1.12–1.51)
	Indirect: post-traumatic stress disorder symptoms[21]	Figure 2: a2*b2	0.94 (0.85–1.01)	0.95 (0.86–1.01)
	Indirect: Depression symptoms	Figure 2: a3*b3	0.93 (0.86–0.98)	0.82 (0.70–0.93)
	Indirect: Pain	Figure 2: a4*b4	1.06 (0.71–1.58)	1.48 (1.04–2.47)
Non-amputation injury (*v.* uninjured group)	Direct (unmediated)	Figure 4: c	0.99 (0.71–1.40)	1.38 (0.97–1.93)
	Direct (mediated)	Figure 4: c'	1.01 (0.71–1.46)	1.35 (0.92–1.93)
	Indirect: post-traumatic stress disorder symptoms[1]	Figure 4: a1*b1	1.24 (1.08–1.50)	1.42 (1.19–1.79)
	Indirect: post-traumatic stress disorder symptoms[21]	Figure 4: a2*b2	0.88 (0.76–0.98)	0.92 (0.80–0.99)
	Indirect: Depression symptoms	Figure 4: a3*b3	0.90 (0.80–0.97)	0.76 (0.60–0.87)
	Indirect: Pain	Figure 4: a4*b4	1.02 (0.60–1.62)	1.58 (0.98–2.69)
Amputation injury (*v.* uninjured group)	Direct (unmediated)	Figure 3: c	1.39 (0.85–2.55)	2.37 (1.37–4.00)
	Direct (mediated)	Figure 3: c'	1.27 (0.75–2.35)	2.18 (1.24–3.75)
	Indirect: post-traumatic stress disorder symptoms[1]	Figure 3: a1*b1	1.01 (0.92–1.14)	1.02 (0.85–1.25)
	Indirect: post-traumatic stress disorder symptoms[21]	Figure 3: a2*b2	1.06 (0.99–1.21)	1.06 (0.99–1.22)
	Indirect: Depression symptoms	Figure 3: a3*b3	1.01 (0.94–1.10)	1.03 (0.82–1.28)
	Indirect: Pain	Figure 3: a4*b4	1.21 (0.90–2.15)	1.36 (0.98–2.76)

Model adjusted for age at assessment, rank at sampling and time in years between sampled deployment/injury and completing the DPTGI.
[1]To account for the curvilinear relationship between post-traumatic growth and post-traumatic stress disorder, post-traumatic stress disorders symptoms and post-traumatic stress disorder symptoms squared are included in the model.

factors such as deployment era, age, rank and role in theatre (Bennett et al., 2020). This allows for the study to explore deployment-related PTG in a cohort with very similar experiences on deployment, with the exception of the injury itself. Additionally, this study employs a robust statistical approach including bootstrapping and GSEM to assess mediation, and addressing the curvilinear relationship between PTSD and PTG. Our study has several limitations. Just over a quarter of participants (27.0%) completed the PTG measure more than a year from their original ADVANCE study assessment. Whilst this is a limitation, longitudinal analysis has indicated that previous experience of PTSD is a significant predictor of PTG at future timepoints, indicating that the endorsement of post-traumatic distress at any point facilitates PTG (Dekel, Ein-Dor, & Solomon, 2012). Another limitation is that whilst the response rate was reasonable, minor differences were noted between the responders and non-responders and the number of amputees was relatively small, requiring bootstrap analysis. Despite significant efforts to recruit from hard-to-reach populations, it is possible that groups such as those with worse current mental health or those with worse disability from injury would be less likely to volunteer or less able to take part in the ADVANCE study. The cross-sectional nature of this study only allows for the investigation of association and not causation. Comparisons of the direct effect in the unmediated and mediated models were unlikely to produce interpretable increases/decreases in effect size also due to inconsistent mediation, and thus the total effect of the mediated model was not calculated. This study is limited to only the experience of PTG for male combat-injured personnel, female experience of PTG may well differ (Dyball et al., 2022b). Finally, our GSEM was unable to account for covariation between mental health and pain (Bondesson et al., 2018; Lee et al., 2019).

Injured personnel in the ADVANCE cohort appear to be more likely to perceive beneficial psychological consequences from deployments to Iraq/Afghanistan, though it remains to be seen whether this is maintained in the long term when other health factors such as aging and poorer health-related functioning become more prevalent (Boos et al., 2021). Other events such as the Armed Forces withdrawal from Afghanistan and the Taliban's subsequent return to power might also affect the experience of PTG in this population. Those with amputation injuries appear to be more likely to report a large degree of PTG compared to a frequency-matched uninjured group, whereas those with a non-amputation injury were no more likely to report a large degree of PTG. PTSD, depression and to a lesser extent pain each appear to play a mediating role in the relationship between combat injury and PTG.

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