Three distinct patterns of mental response after mountain sport accidents

Manuscript

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# Abstract

**Background:** Psychological consequences of mountain sport accidents are poorly characterized. We investigated patterns of mental response to mountain sport accidents and their victims at risk of mental deterioration.

**Methods:** A cross-sectional survey was conducted with 307 adult victims of mountain sport accidents treated at the Innsbruck University Hospital (Austria). Anxiety (GAD-7), depression, somatic symptoms and panic (PHQ), resilient comping (RS-13), sense of coherence (SOC-9L), quality of life (EUROHIS), post-traumatic growth (PTGI) and post-traumatic stress disorder (PTSD) were recorded along with demographic, socioeconomic, medical history, accident- and injury-related data. Patterns of mental readouts were defined by semi-supervised medoid clustering and models of cluster assignment based on non-mental measures were developed by the random forest algorithm.

**Results:** Three mental clusters of accident victims were hallmarked by a neutral mental response, post-traumatic growth and post-traumatic burden of mental disorders, respectively. Despite relatively frequent hospitalization, surgery, pre-existing mental or somatic illness, low income, and female gender in the post-traumatic growth and post-traumatic burden clusters, overall differences in non-mental variables between the clusters were weak. Consequently, no reliable model of the cluster assignment employing explanatory factors available during acute medical accident management could be established.

**Conclusion:** A subset of mountain sport accident victims develops symptoms of anxiety, depression, post-traumatic stress disorder and other mental health problems. Since identification of these vulnerable patients with demographic, socioeconomic, accident- and injury-related predictors remains challenging, early and low-threshold psychological support is key to prevention of mental disorders following mountain sport accidents.

# Keywords

mountain sport accident, mental health, post-traumatic stress disorder, post-traumatic growth, clustering, random forest, machine learning

# Introduction

Stress-related manifestations following an experience or witnessing of a traumatic event such as actual or threatened death, injury, physical or sexual violence amount to post-traumatic stress disorder (PTSD). PTSD symptoms include hyperarousal, panic, somatic symptoms, sleep disorders and unwilling recalls of the trauma (flashbacks) (1–3) and are classified as chronic when lasting over three months (4). Of note, PTSD may overlap with signs of depression, anxiety and substance abuse (5,6). Although most individuals have experienced at least one traumatic event during the lifetime (7,8), the prevalence of PTSD in the general population was estimated for 6 - 9% (9,10). Factors pre-disposing for PTSD include repeated trauma exposition e.g. in a family (11) or professional setting (12), female gender (13) or young age (14). Yet, effects of early demographic or clinical predictors available during acute medical or psychiatric management of traumatic events on PTSD risk are weak (15). Hence identification of PTSD-vulnerable population is challenging and hampers effective prevention measures (15,16). Post-traumatic growth describes a salutary adjustment psychological reaction to a traumatic experience including boosted attitude to life, self and relationship (17). It is disputable, if resilience, i.e. ability to adapt to stress or trauma (1), represents a pre-existing personality trait or a feature that can be modified by a potentially traumatic event (18). The interplay between PTSD, post-traumatic growth and resilience is still unclear. While resilience is considered to protect from PTSD development, symptoms of both PTSD and post-traumatic growth may co-occur in a subset of trauma affected individuals (19,20).

While outdoor physical activity has been shown to foster mental health (21,22), mountain sports are also associated with an elevated risk of injury (23). Physical injury frequently perceived as a life-threatening induces a response of fear (24), and up to 26% of acute trauma injury patients were reported to develop PTSD (25). PTSD frequency in accident victims was found to be associated with head injuries, hospitalization length and pain (16). Literature on mental distress following traumatic events related to mountain sports is scarce and discrepant. In studies with mountain guides and mountain rescue personnel, 71 - 78% of participants had experiences traumatic events (26,27). Intriguingly, the frequency of PTSD symptoms ranged between 1 - 2.7% which was less than in the general population and, particularly, much lower than in other vulnerable groups such as emergency workers (12,26,27). Moreover, significantly higher resilience levels than in the general population were reported (27). By contrast, PTSD symptom prevalence reported by Traber et al. in a similar collective of mountain professionals was 22% (28). Concerning alpine accidents, survivors of avalanches were affected by acute and long-term PTSD symptoms such as hyperarousal or sleep disorders at rates between 11 - 16% (29,30). Still, a more general psychological reaction to a mountain accident, which may trigger PTSD-like distress, post-traumatic growth or resilience boost, has not been yet characterized.

Herein, we sought to explore patterns of mental health in a collective of 307 mountain accident victims in Tyrol, Austria, screened for signs of PTSG, post-traumatic growth, deteriorating quality of life and major psychiatric problems. Additionally, we searched for early demographic, socioeconomic and clinical predictors of mental health disorders following a mountain accidents which may help to tailor early preventive psychiatric interventions.

# Methods

## Ethics

The study was conducted in accordance with the Declaration of Helsinki and European data policies. All participants gave electronically signed written informed consent to participate. Participants’ data were processed in anonymized form. The study protocol was approved by the ethics committee of the Medical University of Innsbruck (approval number: *please fill in!*).

## Participants

In- and outpatients treated at the orthopedics and trauma departments of the Medical University of Innsbruck (Austria) between 2018 and 2020 were screened for participation. Patients fulfilling the inclusion criteria: age 16 years, proficiency in German and treatment due to a mountain sport accident (n = 4559) were invited to participate in the online study survey. Out of them, 370 completed the survey and 307 individuals with the complete psychometry data were analyzed (**Figure 1**, **Supplementary Tables S1** - **S2**).

## Procedures

Details on study procedures and variables are provided in **Supplementary Methods** and **Supplementary Table S1**.

The psychometric battery consisted of German versions of assessment tools for anxiety (GAD-7: 7-item general anxiety disorder scale) (31), depression (PHQ: patient health questionnaire, PHQ-9) (32,33), panic (PHQ-panic module) (32,33), persistent somatic symptoms (PHQ-15) (34), resilient coping (RS13: 13-item resilience scale) (35), loss of sense of coherence (SOC-9L: Leipzig 9-item sense of coherence questionnaire) (36), quality of life (EUROHIS-QOL 8: 8-item EUROHIS project quality of life scale) (37), post-traumatic growth (PTGI: post-traumatic growth inventory) (17) and post-traumatic stress disorder (PCL-5 DSM-5: PTSD checklist for DSM-5) (38). The tools displayed good-to-excellent consistency (39) (McDonald’s > 0.8, **Supplementary Table S2** and **S3**). Signs of anxiety (GAD-7 10), depression (PHQ-9 11) (40), persistent somatic symptoms (PHQ-15 11) (34) and resilient coping classes (low: RS-13 0 - 65, moderate: 66 - 72, high: 73)(35) were defined as described before. The total PTGI and PCL-5 DSM-5 scores were calculated as the sum of all items of the respective tools (17,38). Significant PTSD symptoms were defined as positivity in at least one PCL-5 DSM-5 domain (38).

Traumatic events before the accident were assessed with the DIA-X tool (41). Flashbacks frequency was surveyed as none, > 1/month and > 1/year. Smoking was surveyed as a single yes/no question. Alcohol abuse was investigated with the CAGE tool (42). Data on injury (AIS: abbreviated injury scale) (43) and medical treatment were extracted from electronic patient’s records.

The training and test participant subsets (2:1 size ratio) were obtained by random splitting which minimized differences in accident year, age, gender, pre-existing traumatic events, somatic and mental illness, and injury severity (**Figure 1**). The training subset size (n = 204) was sufficient for clustering analysis as assessed by Hopkins metrics = 0.72 (44).

## Analysis endpoints

The primary analysis endpoint was identification of subsets of mountain sport accident victims by clustering in respect to scores of anxiety, depression, panic, persistent somatic symptoms, quality of life, post-traumatic growth and post-traumatic stress disorder. The secondary analysis endpoints were demographic, socioeconomic and clinical characteristic of the mental clusters and development of a mental cluster assignment model to discern accident victims at risk of mental disorders.

## Statistical analysis

Details on statistical analysis are provided in **Supplementary Methods**

Statistical analysis was done with R version 4.2.3. Numeric variables are displayed as medians with interquartile ranges. Categorical variables are presented as percentages and counts. Differences in numeric variables were analyzed by Mann-Whitney or Kruskal-Wallis test with r or effect size statistics. Differences in categorical variable distribution were assessed by test with Cramer V effect size statistic (45).

The training subset was clustered in respect to normalized median-centered psychometric scores by partition around medoids with cosine distance (46,47). This algorithm had a good explanatory performance (ratio of between-cluster sum of squares to total sum of squares) and the superior accuracy in 10-fold cross-validation (48) as compared with the hierarchical and KMEANS algorithms. The k = 3 cluster number choice was based on the bend of within-cluster sum of squares curve and maximal mean silhouette statistic (44,49). The training subset observations were assigned to the clusters with an inverse distance weighted 7-nearest neighbor classifier.

Multi-parameter classifiers were trained with the conditional random forest algorithms (50–52). The cluster assignment was predicted for the test subset and assessed by the accuracy and statistics (53). Permutation variable importance in the random forest classifiers was expressed as accuracy loss (54).

# Results

# Characteristic of the study cohort

In- and outpatient adult victims of mountain sport accidents treated at the Medical University of Innsbruck (Austria) between 2018 and 2020 were invited to participate (n = 4559). Out of them, 370 completed the study survey and 307 individuals with the complete psychometric parameter set were analyzed (overall response rate: 6.7%, **Figure 1**, **Supplementary Tables S1** - **S3**).

As compared with the participants, the individuals excluded from the analysis had lower income, less frequent ski and more frequent biking accidents, less severe injuries, and lower hospitalization and surgery rates. The excluded individuals had also lower ratings of post-traumatic growth ratings and lower sense of coherence. Effects of these differences were weak (V 0.22 or r 0.15, **Supplementary Table S4**).

In the analyzed cohort, the median time between the medical accident management and survey completion was 1343 days. The participants were predominantly middle-aged (median 51 years) and 45% of them were females. The vast majority had secondary or tertiary education grade and were professionally active. Sport and trauma-risk professions constituted < 8% of the cohort. High annual household incomes of 45000 Euro was reported by > 40% of participants. Less than 10% of participants were smokers or at risk of alcohol addiction. Chronic somatic conditions prior to the accident were reported by 15% of participants with cardiovascular, neurological and metabolic illness being the most frequent. The rates of smoking (Austria: 20.6%) and somatic illness (38.3%) were lower than in the general Austrian population (55,56). Psychiatric disorders before the accident affected 5.2% of the cohort. Four of ten participants were affected by or witnessed a traumatic event prior to the accident (**Table 1**).

Nearly 40% of participants had sport accidents in the past. Almost two-thirds of the investigated accidents happened during skiing or snowboarding followed by biking and classical mountain sports such as climbing, hiking or mountaineering. One-third participants were alone during the accident and, in most cases, were the sole culprit and victim. Roughly half of participants could rescue themselves, 29% required a professional rescue. In 35% of participants the injury was moderate (AIS 2) and in 28% severe-to-critical (AIS 3). Limb injuries were the most common followed by head and face (**Supplementary Figure S1A**). Hospitalization and surgery rates were 26% and 14%, respectively. Psychological or psychiatric support after the accident was applied to 9.1% individuals. Among those who had not received it, 7.5% declared psychological support need. Despite fairly common somatic health consequences of the accident (37%) and flashbacks during sport (40%), most participants returned to the accident sport type ( 85%). Yet, two-third described their behavior during sport as more cautious (**Table 2**).

Signs of anxiety (2.3%), depression (5.5%) and persistent somatic symptoms (4.9%) were rare in the study cohort (**Table 3**). Quality of life was rated with median 4.4 EUROHIS points, which was comparable to the generalized Western European population (37); overall quality of life and housing domains received the highest ratings. Roughly two-thirds of participants were assigned to the high resilient coping class (35). Overall post-traumatic growth (median: 32) and its specific domains were rated lower than originally reported for the PTGI tool (17). Symptoms of post-traumatic stress disorder were observed in 19% of participants with domain B symptoms (11%) being most common (**Table 3** and **Supplementary Figure S1**).

For clustering and modeling, the cohort was split into the training (n = 204) and test subset (n = 103). There were no significant differences between the subsets in demographic, socioeconomic, clinical and accident-related parameters (not shown).

# Three clusters of mental response in sport accident victims

To explore mental responses to mountain sport accidents, we subjected the participants to clustering in respect to a broad range of numeric psychometry variables (**Supplementary Table S2**). Among clustering algorithms compared in the training subset, partition around medoids with cosine distance (46,47) demonstrated good explanatory power and superior reproducibility in cross-validation (48) (**Supplementary Figure S2A**). Three mental clusters: ‘neutral’, ‘PTG’ (post-traumatic growth) and ‘PTB’ (post-traumatic burden), named after their key mental characteristic were identified in the training subset. Subsequently, the mental cluster assignment could be robustly validated in the test subset as evident from comparable fractions of explained clustering variance (training: 0.54, test: 0.54), comparable cluster sizes and good visual cluster separation in both study cohort subsets (**Supplementary Figures S2B** - **S4**).

The neutral cluster encompassing roughly one-third participants was characterized by low levels of anxiety, depression, panic, somatic symptoms, post-traumatic stress and post-traumatic growth along with high rating of coherence, resilient coping and quality of life. The PTG cluster demonstrated similarly low scores of major mental health disorders. By contrast, levels of post-traumatic growth were the highest in the PTG cluster. Furthermore, ratings of post-traumatic stress were slightly higher in the PTG than in the neutral cluster. The remaining PTB cluster displayed the highest scores of anxiety, depression, panic, somatic symptoms and post-traumatic stress as well as poor sense of coherence, resilient coping and low quality of life. Post-traumatic growth scores in the PTB cluster were higher than in neutral but lower than in PTB cluster participants (**Figure 2**, **Supplementary Table S5**). Consequently, clinically relevant symptoms of anxiety, depression and persistent somatic symptoms were present virtually only in the PTB cluster. Furthermore, frequencies of low and moderate resilient classes peaked in the PTB cluster. Finally, symptoms of post-traumatic stress disorder were way more frequent in the PTB cluster (any symptoms: > 36%) than in the remaining clusters (**Figure 3**).

Collectively, the PTG cluster may represent individuals with salutary reaction to mountain sport accident, whereas the PTB cluster may pose a group at risk of mental health deterioration.

# Demographic, socioeconomic and clinical background of the mental clusters

Among 51 investigated demographic, socioeconomic, clinical, accident- and accident consequence-related variables, only 5 parameters were found to differ significantly between the mental clusters in both the training and test subsets. The effect size of such differences was weak (**Supplementary Table S6**).

A substantial enrichment of females, low-to-middle income and non-tertiary education participants was observed in the PTB cluster. The PTG cluster had the highest share of middle-aged individuals. Frequency of somatic conditions before the accident were the highest in the PTG and PTB clusters. Participants with pre-existing mental illness were in turn represented virtually only in the PTB cluster. Although frequencies of previous sport accidents were comparable between the clusters, PTG cluster individuals were affected by prior traumatic events more often than neutral cluster individuals. These differences were, however, non or borderline significant and of weak effect size (**Figure 4**, **Supplementary Figure S5**). There were no consistent differences in accident sport type, rescue, injury severity and location between the mental clusters. Yet, PTG and PTB cluster individuals tended towards higher hospitalization and surgery rates (**Figure 5** and **Supplementary Figure S6**).

Somatic health consequences of the accident and flashbacks were significantly more common in the PTB than the neutral cluster. Additionally, PTG and PTB cluster individuals tended towards more caution during sport as compared with the neutral cluster. Roughly one-sixth PTB cluster individuals reported need for psychological support following the accident as compared with none in the neutral cluster. Rates psychological support after the accident tended to be higher in the PTG (12 - 16%) than in the remaining clusters, yet this effect was significant only in the training subset (**Figure 6**). Given the low frequency of psychological support after the accident in the study cohort and particular clusters, it is unlikely, that psychological support affected the mental cluster assignment .

# Prediction of the mental cluster assignment by demographic, socioeconomic and accident-related factors

Finally, we intended to model the mental cluster assignment with 39 demographic, socioeconomic, clinical and accident-related factors available during acute medical management of the accident (**Supplementary Table S7**). Such models would enable early identification of mountain sport accident victims at risk of mental health problems.

This multi-parameter conditional random forest model (6,50–52) employing early candidate cluster predictors could correctly assign 81% training subset observations to their mental clusters ( = 0.71). However, its predictive performance in the test subset was poor (accuracy: 42, = 0.14). The prediction quality was the best for the PTG cluster (accuracy, training: 89.5%, test: 59.4%, **Figure 7A**). The most important early explanatory variables for the cluster prediction by conditional random forests were annual income, sex, mode of rescue, leg injury and pre-existing mental illness (**Figure 7B**). Inclusion of late accident consequences such as cautious behavior during sport, flashbacks or somatic health burden of the accident in the random forest model could only marginally improve its performance (training: accuracy = 0.82, = 0.72; test subset: accuracy = 0.5, = 0.25). The most important late predictors of the cluster assignment were caution during sport and flashbacks (**Supplementary Figure S7**).

Collectively, we could not establish a reliable model for identification of patients at risk of mental disorders represented by the PTB cluster with a broad ensemble of early non-mental predictors.

# Discussion

In individuals surveyed on average 3.5 years after the non-professional sport accident, some of its consequences like somatic health problems, unwilling flashbacks as well as phenomena of post-traumatic growth and symptoms of post-traumatic stress disorder were still tangible. By semi-supervised clustering we could discern three distinct patterns of mental health in this collective with each present in approximately one-third of participants: (1) a neutral mental response reaction, (2) salutatory reaction to the accident characterized by post-traumatic growth and (3) mental health deterioration hallmarked by mental accident burden such as symptoms of anxiety, depression, somatization, resilience loss and signs of post-traumatic stress disorder. Notably, separation of the PTG and PTB clusters was in part blurry. Symptoms of post-traumatic stress were observed also in PTG cluster participants albeit less frequently than in the PTB cluster. Conversely, mental health problems in PTB cluster participants were paralleled by some signs of post-traumatic growth. In a detailed comparison of 51 factors between the clusters, no distinct demographic, socioeconomic, clinical or accident-related background of the mental clusters could be identified. We found a moderate enrichment of females, low-to-moderate income participants, non-academic graduates, chronic somatic and psychiatric conditions as well as individuals requiring hospitalization and surgery in the PTG and, in particular, in the PTB cluster. Injury severity and localization or professional rescue rates indicative of potentially more severe accident were comparable between the clusters. Similarly, the cluster assignment was unlikely affected by psychological support after the accident. In turn, the PTB and, to a lesser extent, the PTG cluster were characterized by somatic health consequences of the accident, flashbacks, more caution during sport activity and subjective need for psychological support. Finally, the lacking non-mental explanatory variables strongly associated with the cluster assignment likely resulted in sub-optimal performance of machine learning classifiers employed for prediction of the cluster assignment and identification of accident victims at risk of mental health problems.

*Hanna and Katharina: your turn now:)*

Our study bears limitations. First, although the key phenomena phenomena in the newly identified mental clusters, post-traumatic growth and post-traumatic stress disorder, are clearly associated with trauma (17,38), we could not exclude the mental cluster assignment to be affected by other events than the sport accident. To account for that, follow-up studies including a control group are needed. Second, our variable set misses potentially important explanatory factors for the mental cluster classification such as length of hospital stay, rehabilitation need or ability to work. Finally, effects of the accident, injury severity, hospitalization or surgery on mental health after an accident may have been obscured in the cross-sectional cohort and needs to be investigated in a more defined collective e.g. of high risk sport accident victims or hospitalized individuals.

# Conclusion

*Your part again please*

# Acknowledgments

# Author’s contribution

# Conflict of interest

# Data and code availability

An R data (RData) file with anonymized patient data will be made available upon request to the corresponding author. The study analysis pipeline is available at <https://github.com/PiotrTymoszuk/mental_accident>.

# Tables

Table 1: Demographic and socioeconomic characteristic of the study cohort. Numeric variables are presented as medians with interquartile ranges (IQR). Categorical variables are presented as percentages and counts within the complete observation set.

| **Variablea** | **Statistic** |
| --- | --- |
| Participants, n | 307 |
| Hospital visit – survey time, days | 1300 [IQR: 800 - 1400], range: 390 - 1600 |
| Age, years | 51 [IQR: 33 - 60], range: 18 - 82 |
| Age class, years | 16-30: 20% (n = 61) 31-65: 66% (n = 202) >65: 14% (n = 44) |
| Sex | female: 45% (n = 137) male: 55% (n = 170) |
| Residence in the Alps | 73% (n = 225) |
| Education | primary/apprenticeship: 16% (n = 49) secondary: 38% (n = 115) tertiary: 45% (n = 136) |
| Employment | employed: 68% (n = 210) unemployed: 3.6% (n = 11) student: 10% (n = 32) retired: 18% (n = 54) |
| Sport profession | 5.2% (n = 16) |
| Trauma-risk profession | 7.2% (n = 22) |
| Income/year | no income: 21% (n = 63) < 30000 EUR: 18% (n = 56) 30000 - 45000 EUR: 19% (n = 59) ≥ 45000 EUR: 42% (n = 129) |
| Smoking | 7.8% (n = 24) |
| Alcohol abuse (CAGE ≥2) | 9.4% (n = 29) |
| Pre-existing somatic illness type | none: 85% (n = 260) CVD: 2.9% (n = 9) neurological: 1.3% (n = 4) metabolic: 1.3% (n = 4) pulmonary: 0.65% (n = 2) cancer: 0.65% (n = 2) rheumatoid: 0.33% (n = 1) skin: 0.33% (n = 1) other: 7.8% (n = 24) |
| Pre-existing mental illness | 5.2% (n = 16) |
| Prior traumatic event/DIA-X | 40% (n = 124) |
| aCAGE: Cut/Annoyed/Guilty/Eye substance abuse scale; DIA-X: Diagnostic Expert System, traumatic event score | |

Table 2: Characteristic of the sport accident, injury, psychological management and accident consequences. Numeric variables are presented as medians with interquartile ranges (IQR). Categorical variables are presented as percentages and counts within the complete observation set.

| **Variable** | **Statistic** |
| --- | --- |
| Prior sport accidents | 38% (n = 118) n = 307 |
| Sport typea | ski/snowboard: 64% (n = 197) sledding: 3.9% (n = 12) climbing/hiking/mountaineering: 14% (n = 42) biking: 16% (n = 48) other: 2.6% (n = 8) n = 307 |
| Alone during the accident | 32% (n = 97) n = 307 |
| Accident culprit | self: 77% (n = 237) non-self: 23% (n = 70) n = 307 |
| Injured persons | only self: 64% (n = 195) self and partner: 3.6% (n = 11) 3+ persons: 1.3% (n = 4) no information: 32% (n = 97) n = 307 |
| Rescue | self: 50% (n = 155) partner/third party: 21% (n = 63) rescue team: 29% (n = 89) n = 307 |
| Injury severity class, AIS | 1: 37% (n = 108) 2: 35% (n = 103) 3+: 28% (n = 83) n = 294 |
| Hospitalizedb | 26% (n = 80) n = 307 |
| Surgery | 14% (n = 43) n = 307 |
| Psychological support | 9.1% (n = 28) n = 307 |
| Psychological support need | 7.5% (n = 23) n = 307 |
| Somatic accident aftermath | 37% (n = 115) n = 307 |
| Returned to same sport | 85% (n = 262) n = 307 |
| Caution post accident | no change: 35% (n = 106) more cautious: 65% (n = 199) less cautious: 0.65% (n = 2) n = 307 |
| Flashback frequency | none: 60% (n = 185) > 1/month: 18% (n = 54) > 1/year: 22% (n = 68) n = 307 |
| aski/snowdoard: alpine skiing, snowboarding and cross-country skiing sledding: sledding or bobsled climbing/hiking/mountaineering: hiking, rock and ice climbing, mountaineering, skitouring biking: mountainbike, tour and road cycling | |
| bAIS: abbreviated injury scale | |

Table 3: Mental health characteristic of the study participants at survey completion. Numeric variables are presented as medians with interquartile ranges (IQR). Categorical variables are presented as percentages and counts within the complete observation set.

| **Variablea** | **Statistic** |
| --- | --- |
| Participants, n | 307 |
| GAD-7 score | 1 [IQR: 0 - 3], range: 0 - 15 |
| Anxiety symptoms (GAD-7 ≥10) | 2.3% (n = 7) |
| PHQ-9 score | 2 [IQR: 1 - 5], range: 0 - 16 |
| Depression symptoms (PHQ-9 ≥11) | 5.5% (n = 17) |
| PHQ-15 score | 2 [IQR: 1 - 4], range: 0 - 23 |
| Somatization symptoms (PHQ-15 ≥11) | 4.9% (n = 15) |
| EUROHIS-QOL 8 score | 4.4 [IQR: 4 - 4.6], range: 2 - 5 |
| SOC-9L score | 19 [IQR: 16 - 25], range: 10 - 49 |
| RS13 score | 78 [IQR: 70 - 85], range: 15 - 91 |
| RS13 coping class | low: 18% (n = 56) moderate: 14% (n = 42) high: 68% (n = 209) |
| PTGI score | 32 [IQR: 16 - 48], range: 0 - 100 |
| PCL-5 DSM-5 score | 3 [IQR: 1 - 7], range: 0 - 44 |
| PTSD+ (at least one domain) | 19% (n = 58) |
| aGAD-7: 7-item general anxiety disorder scale; PHQ: patient health questionnaire; EUROHIS-QOL 8: 8-item EUROHIS project quality of life scale; SOC-9L: Leipzig 9-item sense of coherence questionnaire; RS13: 13-item resilience scale; PCL-5 DSM-5: PTSD checklist for DSM-5; PTGI: post-traumatic growth inventory; PTSD: post-traumatic stress disorder | |

# Figures

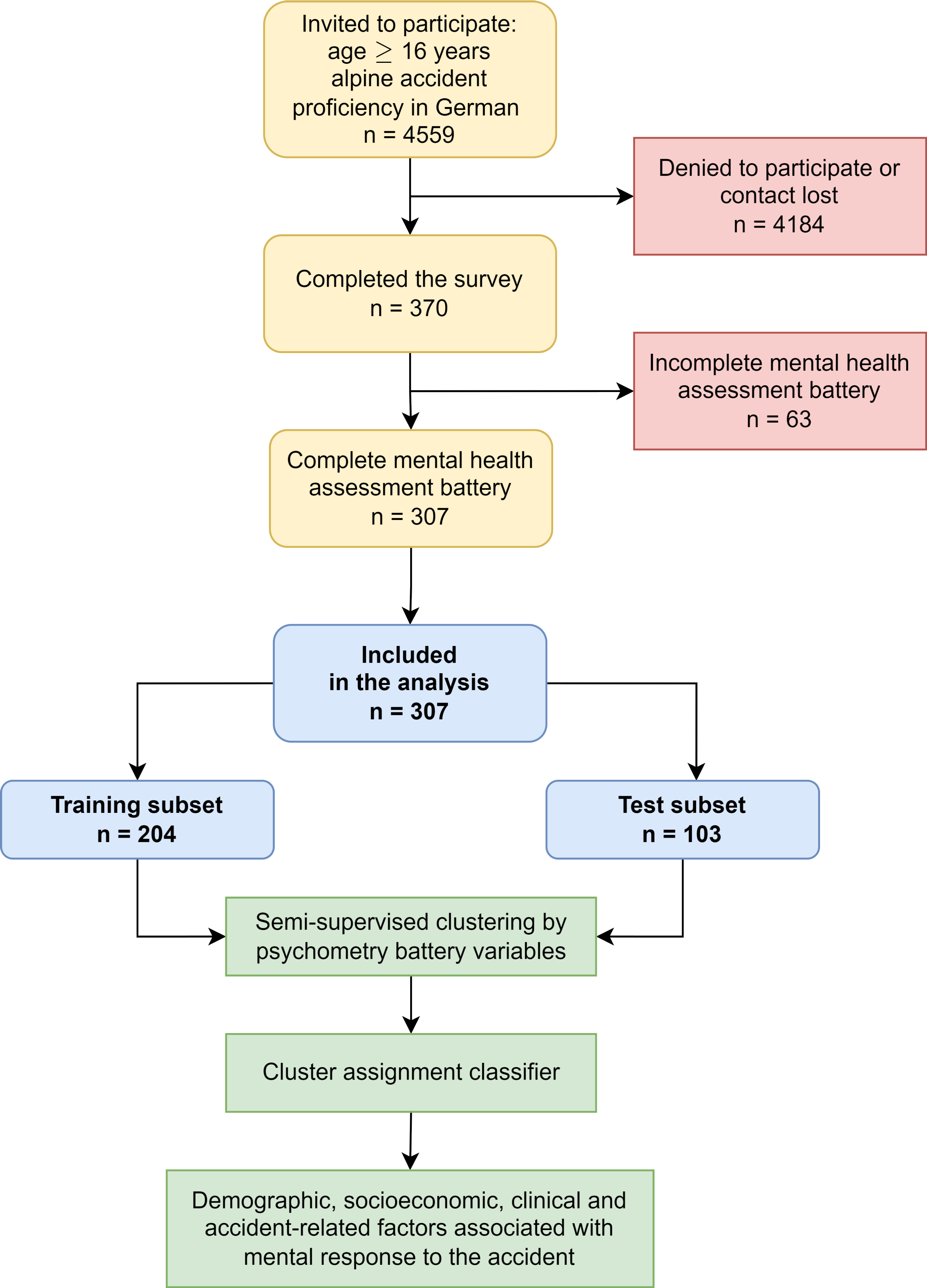


Figure 1: Flow diagram of the analysis inclusion process and the analysis strategy.

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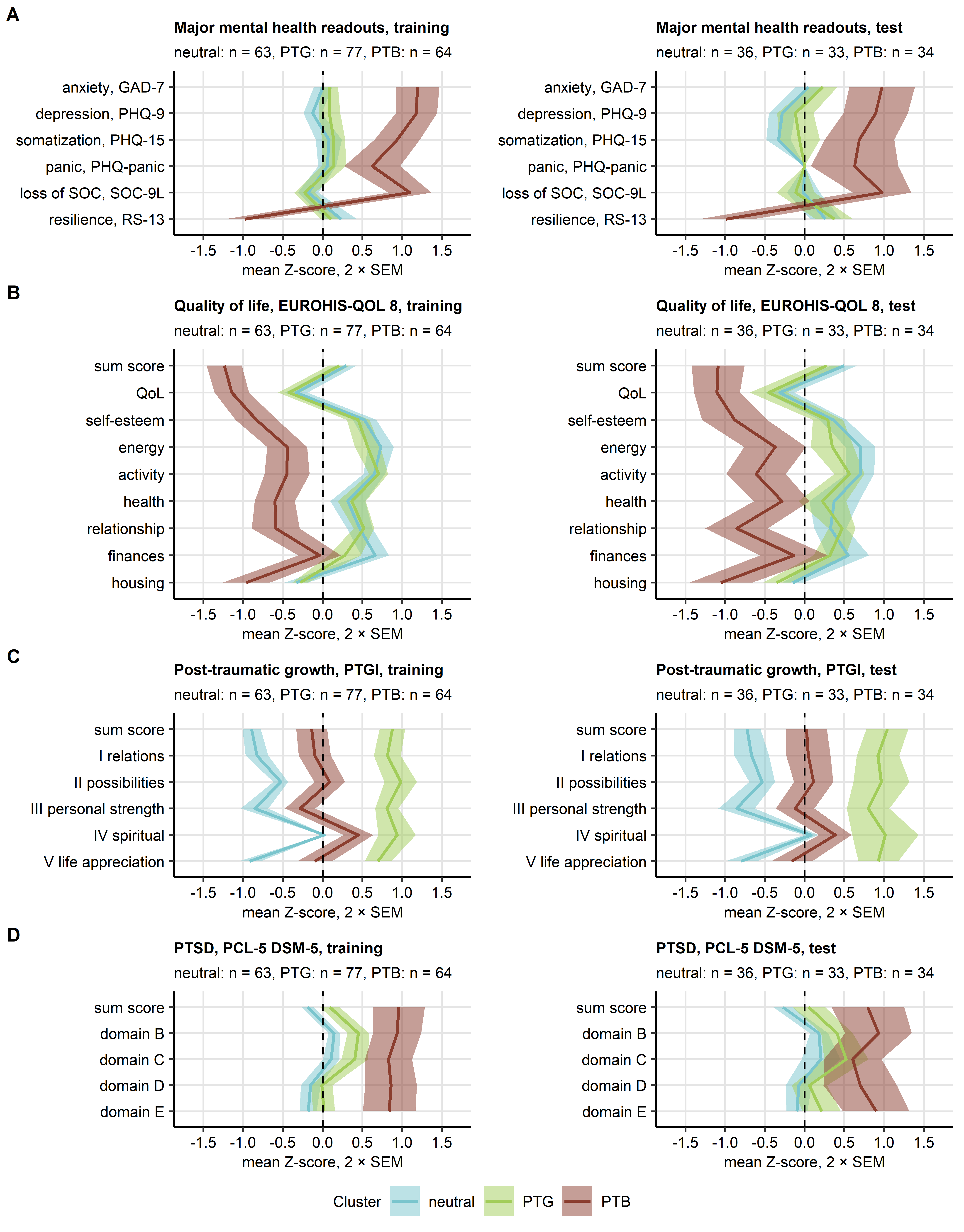


Figure 2: Scores of psychometry readouts in the mental clusters.

**Figure 2. Scores of psychometry readouts in the mental clusters.**

*The mental clusters were defined in respect to psychometric scoring in the training subset of the study cohort by PAM (partition around medoids) with cosine distance between the observations. Assignment of the test subset observations to the mental clusters was done with the inverse distance weighted 7-nearest neighbors classifier. Three mental clusters were identified: neutral, PTG (post-traumatic growth) and PTB (post-traumatic burden), All clustering parameters differed significantly between the clusters as assessed by Kruskal-Wallis test with effect size statistic. Mean normalized scores of major mental health readouts (A), diminished quality of life (B), post-traumatic growth (C) and post-traumatic symptom disorder (D) in the mental clusters of the training and test subsets of the study cohort are depicted as solid lines. Tinted regions represent 2 SEM (standard error of the mean). Numbers of observations in the clusters are displayed in the plot captions. GAD-7: 7-item general anxiety disorder scale; PHQ: patient health questionnaire; EUROHIS-QOL 8: 8-item EUROHIS project quality of life scale; SOC-9L: Leipzig 9-item sense of coherence questionnaire; RS13: 13-item resilience scale; PCL-5 DSM-5: PTSD checklist for DSM-5; PTGI: post-traumatic growth inventory; PTSD: post-traumatic stress disorder.*

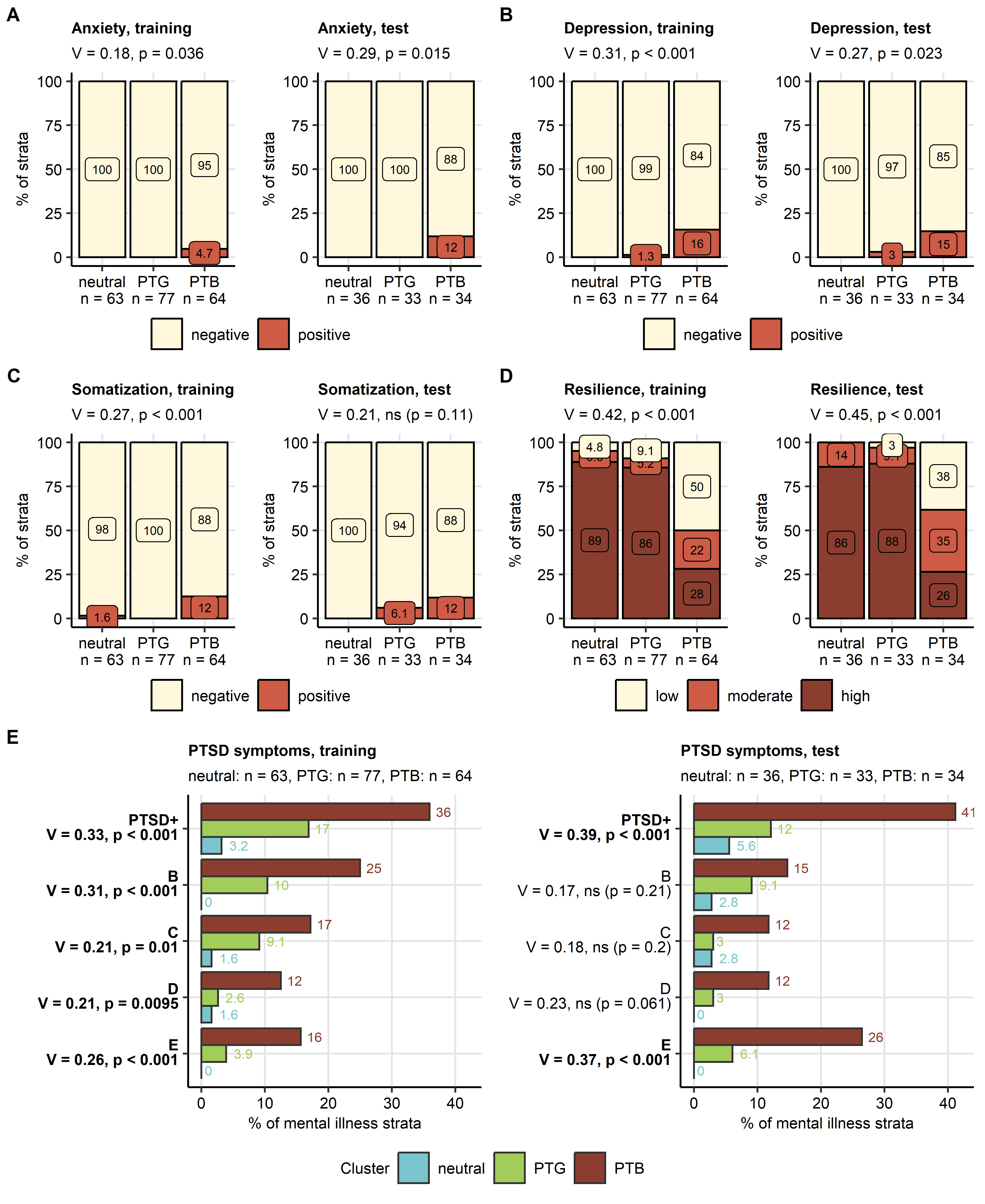


Figure 3: Signs of mental health problems in the mental clusters.

**Figure 3. Signs of mental health problems in the mental clusters.**

*Frequencies of symptoms of anxiety (A, GAD-7 ≥10), depression (B, PHQ-9 ≥ 11) and somatization (C, PHQ-15 ≥ 11), distribution of resilient coping classes (D, RS13) and symptoms of post-traumatic stress disorder (E, PTSD, PCL-5 DSM-5, positivity for PTSD domains and frequency of participants positive for at least one PTSD domain [PTSD+]) in the mental clusters. Statistical significance was determined by test with Cramer V effect size statistic. Fractions of symptom-positive and -negative participants in the mental clusters in the training and test subset of the study cohort are presented in stack and bar plots. Effect sizes and p-values are shown in the plot captions or Y axes. Numbers of observations in the clusters are shown in the X axes or plot captions. Significant effects in (E) are highlighted in bold. GAD-7: 7-item general anxiety disorder scale; PHQ: patient health questionnaire; RS13: 13-item resilience scale; PCL-5 DSM-5: PTSD checklist for DSM-5; PTSD: post-traumatic stress disorder.*

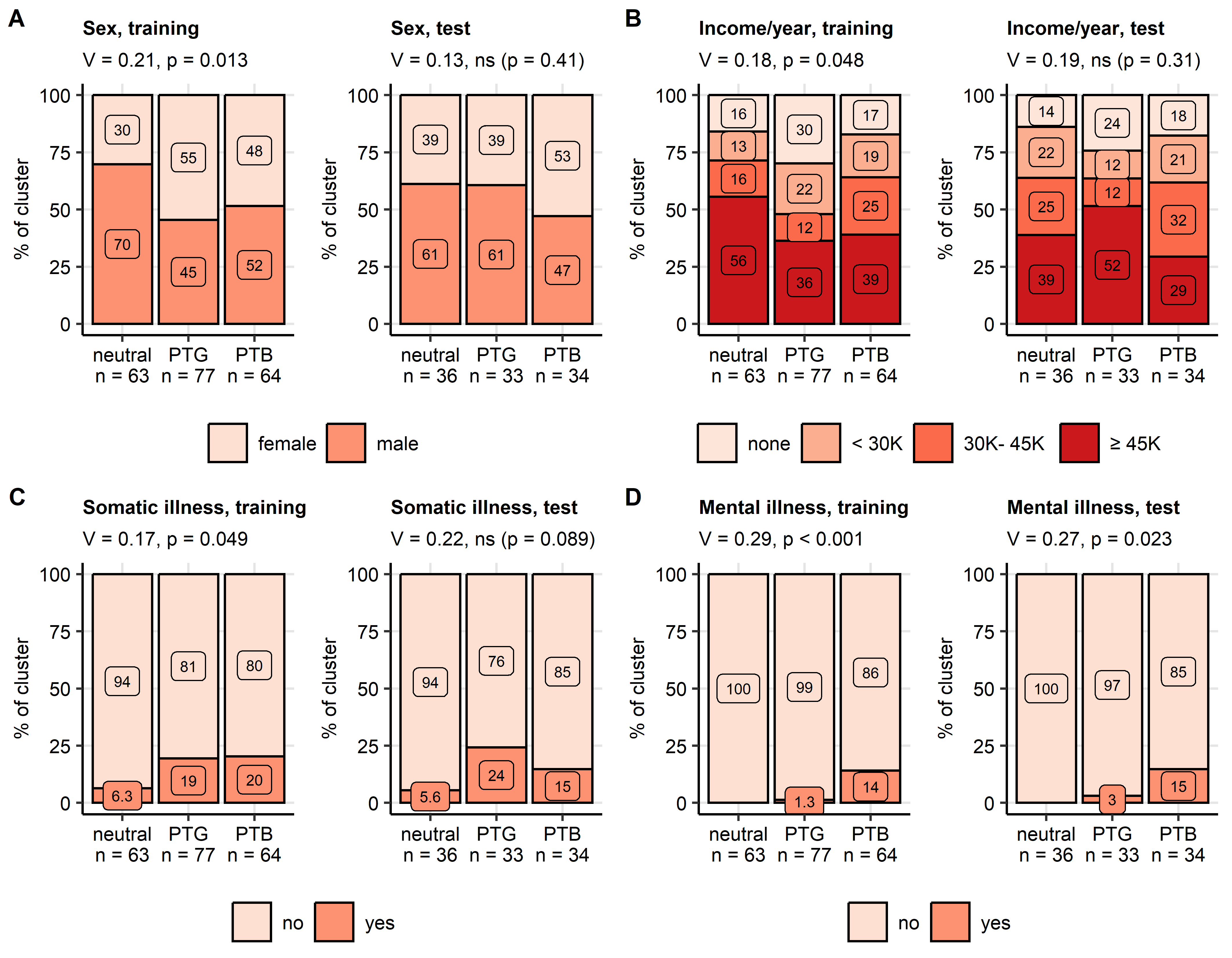


Figure 4: Demographic and clinical factors differing between the mental clusters of accident victims.

**Figure 4. Demographic and clinical factors differing between the mental clusters of accident victims.**

*Distribution of gender (A), annual household income (B), and frequencies of self-reported pre-existing somatic conditions (C) and self-reported pre-existing mental illness (D) in the mental clusters. Statistical significance was determined by test with Cramer V effect size statistic. Percentages in the mental clusters in the training and test subset of the study cohort are presented in stack plots. Effect sizes and p-values are displayed in the plot captions. Numbers of observations in the clusters are presented in the X axes.*

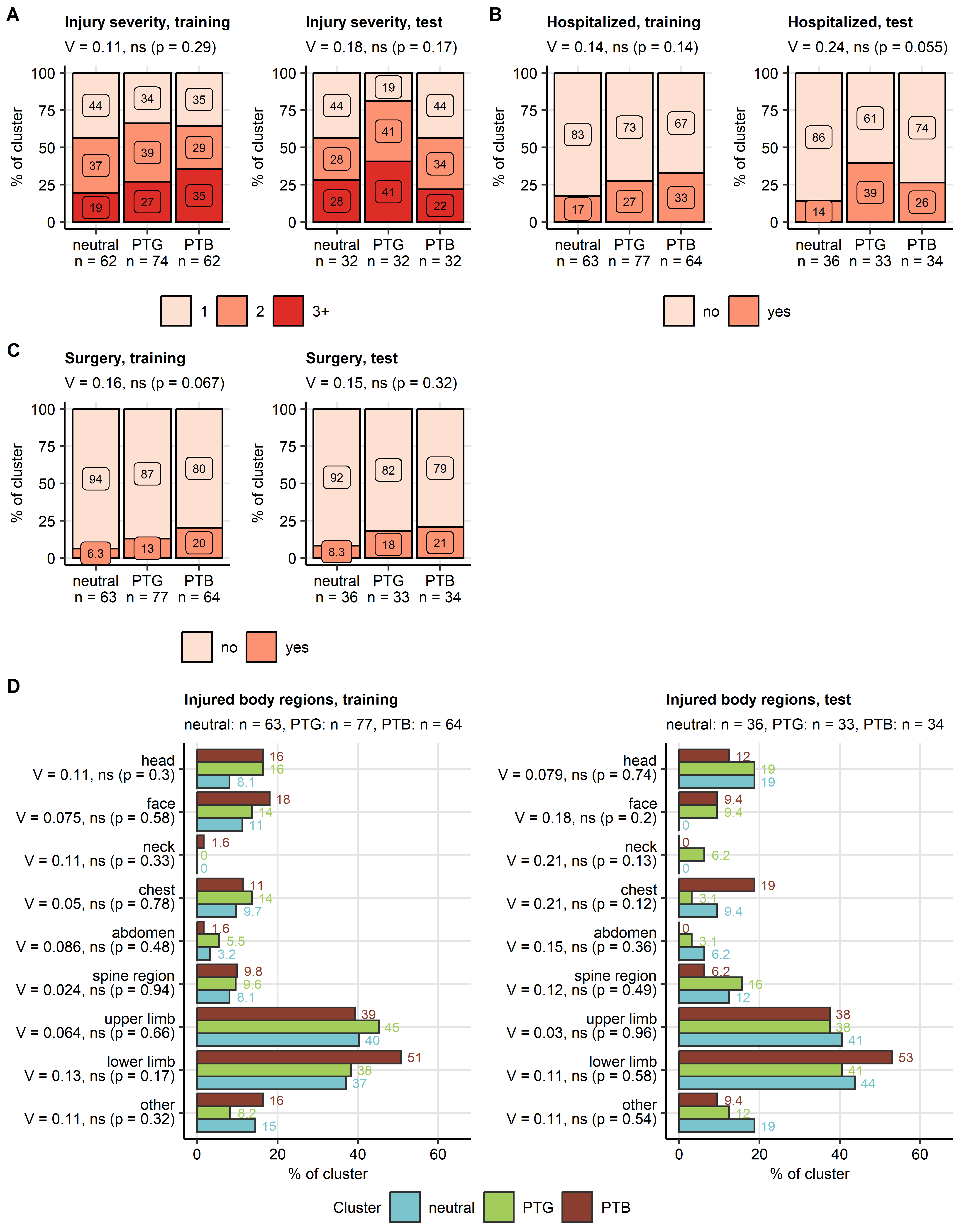


Figure 5: Injury severity and location in the mental clusters.

**Figure 5. Injury severity and location in the mental clusters.**

*Distribution of injury severity grades (A, AIS: abbreviated injury scale), hospitalization (B) and surgery rates (C), and injuries of the body parts (D) in the mental clusters. Statistical significance was determined by test with Cramer V effect size statistic. Percentages in the mental clusters in the training and test subset of the study cohort are presented in stack and bar plots. Effect sizes and p-values are displayed in the plot captions or Y axes. Numbers of observations in the clusters are presented in the X axes or plot captions.*

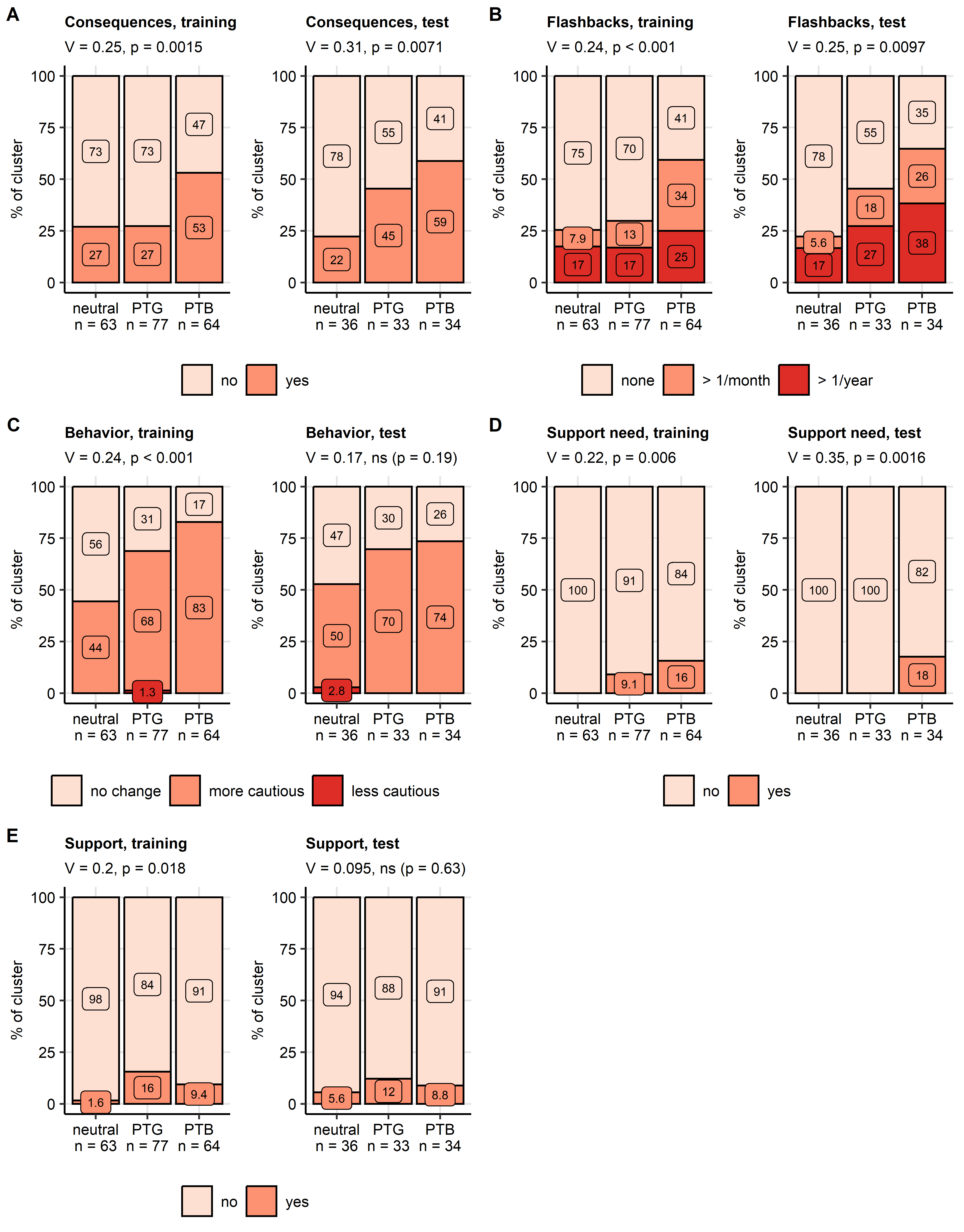


Figure 6: Consequences of the accident in the mental clusters.

**Figure 6. Consequences of the accident in the mental clusters.**

*Frequencies of self-reported somatic health consequences of the accident (A), flashbacks during sport (B), more or less cautious behavior during sport activity (C), self-reported psychological support need (D) and of a received psychological support (E) in the mental clusters. Statistical significance was determined by test with Cramer V effect size statistic. Percentages in the mental clusters in the training and test subset of the study cohort are presented in stack plots. Effect sizes and p-values are displayed in the plot captions. Numbers of observations in the clusters are presented in the X axes.*

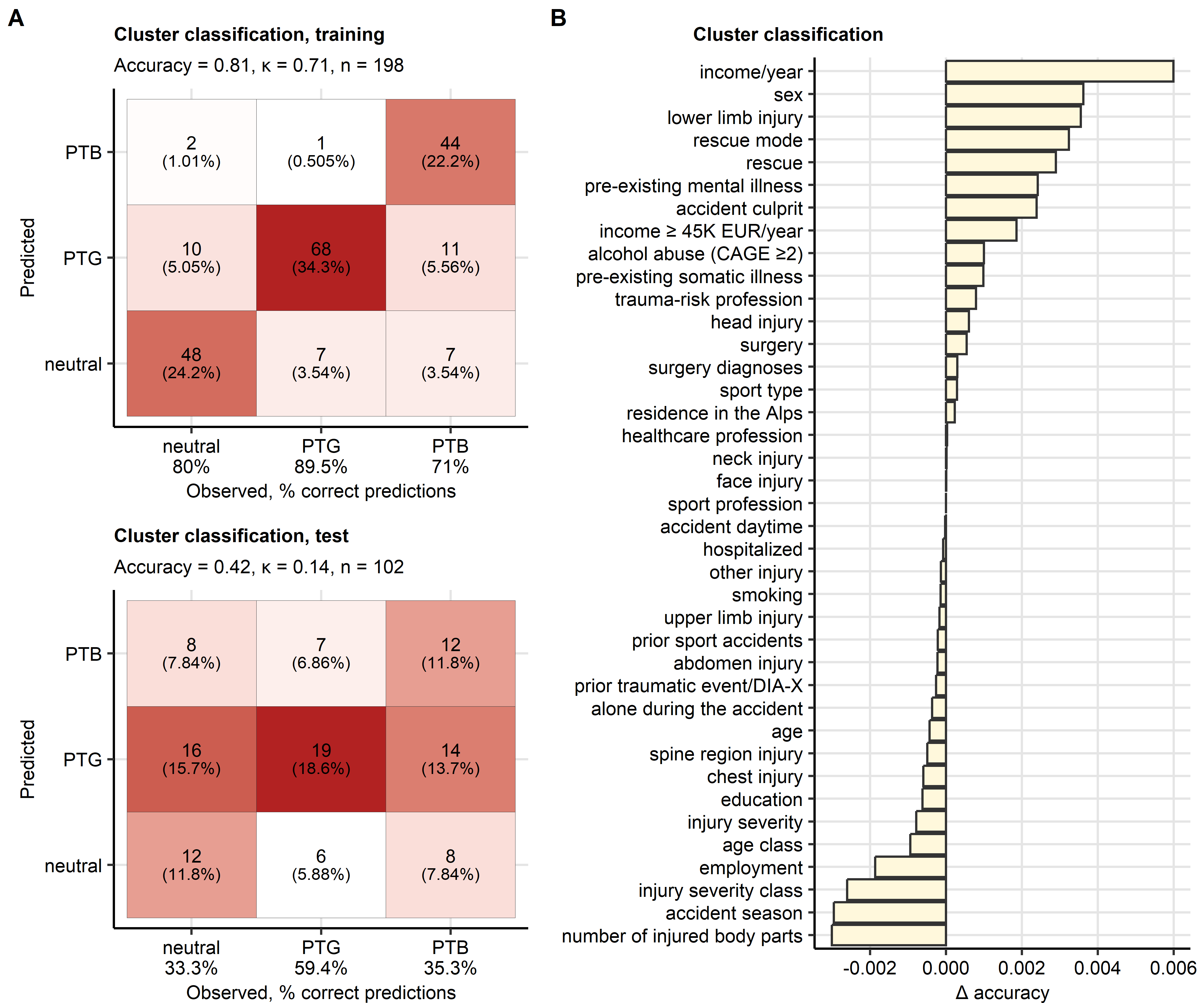


Figure 7: Assignment of accident victims to the mental clusters based on explanatory factors available during acute medical management of the accident.

**Figure 7. Assignment of accident victims to the mental clusters based on explanatory factors available during acute medical management of the accident.**

*A conditional random forest classifier for the mental cluster assignment based on demographic, socioeconomic, clinical and accident-related factors available during acute medical management of the accident was trained in the training subset of the study cohort.*

*(A) Prediction accuracy of the classifier in the training and test subset of the study cohort presented in a heat map plot of the confusion matrices. Color codes for number of cases. The overall prediction accuracy, and observation numbers are displayed in the plot caption. Prediction accuracy for particular clusters is shown in the X axis.*

*(B) Conditional importance of the explanatory variables for prediction of the mental cluster assignment expressed as accuracy loss ( accuracy).*

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