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ABSTRACT

Optimal sport performance involves balancing the accumulation of training stress with adequate recovery (Budgett, 2000; Hollander & Meyers, 1995). Continuous evaluation of an athlete's performance levels, stress levels, and recovery states during a competitive season is important in determining an athlete's readiness for competition. Limited examination of these three factors appears for collegiate athletes; thus this study's purpose was to examine effects of training load on psychological and performance variables among collegiate female athletes across a competitive season. Nineteen NCAA Division I female swimmers completed monthly testing including six tethered swim tests and seven Recovery-Stress Questionnaires (RESTQ-76), yielding mean force (F_{mean}) and Total Recovery-Stress Score (TRSS). Individual session Rated Perceived Exertion scales (RPE) were used to categorize participants into Training Load Groups (TLG). Analysis revealed no significant interaction between TLG, and either TRSS or F_{mean}. There were significant time effects on F_{mean} ($p=0.004$): between T1 and T2 ($p=0.004$), and T3 and T4 ($p=0.01$). There were significant changes in meters completed with differences between T1 and T2 ($p<.001$), between T4 and T5 ($p<.001$), and between T5 and T6 ($p<.001$). TRSS and meters completed had an inverse relationship where an increase in meters occurred concurrently with decreases in TRSS and vice versa. This study's results indicate that, while there was no difference between groups for performance, perceived stress, and recovery, there were significant changes across a season that could have practical implications for athletes, coaches, and researchers.

Introduction

Chronic sport training associated with early sport specialization has increased interest in performance testing and monitoring of competitive athletes to help reduce injury and fatigue. One major concern is promoting the balance between training stress and recovery (Budgett, 2000; Hollander & Meyers, 1995). Although the manifestation of this imbalance is unique to each individual (Saremi, 2009), some commonly experienced symptoms include physiological changes (Urhausen & Kindermann, 2002), psychological changes (Huddleston et al., 2002), and decreased sport performance (Coutts et al., 2007; Halson & Jeukendrup, 2004). Overtraining is not only sport specific, but it is also specific to the athlete where adaptation to training stress and recovery are unique to the individual (Hollander & Meyers, 1995).

Approximately 20% of athletes may exhibit symptoms of overtraining throughout their career (Budgett, 2000; Mackinnon, 2000). Athletes participating in sports such as swimming, triathlons, road cycling, and rowing experience symptoms of overtraining due to the heavy training schedule they perform per week. Furthermore, these predominantly non-weight bearing sports make athletes less susceptible to acute injury, allowing for an even greater capacity for training volume (Mackinnon, 2000). Swimming has been studied frequently (Kreider, 1998) due to the high frequency of training and training sessions that are long in duration, which results in a high training volume (Gonzalez-Boto et al., 2008).

There is a large body of literature identifying symptoms of overtraining and its consequences on athletic performance. However, few studies observe athletes throughout an entire season, with the majority of studies lasting only a portion of the competitive season (2 weeks to 6 months) and rarely extending through a complete training cycle (Kreider, Fry, & O'Toole, 1998; O'Connor et al., 1989). Additionally, most research examines the physiological and psychological implications of overtraining separately, with a majority focusing on the physiological measures of overtraining. However, it is difficult to determine the influence of training stress and recovery when based on one specific measure of overtraining. Furthermore, physiological measures have shown to be inconsistent, where psychological measures have shown to be more reliable if coupled with a measure of performance (Gonzalez-Boto et al., 2008). Previous research has utilized swimming competition results as a measure of performance. However, swim performance has been found to be highly variable because of the inconsistent events and strokes swam, pool lengths, and competition meet formats. Based on the findings of Halson & Jeukendrup (2004), the signs and symptoms of overtraining are generally observed during anaerobic tests of power output. Recent research has used a tethered swimming test as a measure of performance. This test is a sport specific performance test that can be used consistently across time and appears to be a valid and reliable test of power output (Mrouco, 2009; Morouco et al., 2008). Dopsajet and colleagues (2003) demonstrated the validity of the tethered swimming test compared to swimming performance times (Cronbach's $\alpha = 0.8649$), as well as general reliability between tests (Spearman-Brown $r_{tt} = 0.9722$). Furthermore, studies have shown that the pulling force measured during a tethered swim test correlated with swimming performance (Vorontsov et al., 2006). More specifically, mean force (F_{mean}) has been shown to be the best predictor for swimming performance for all competitive swim techniques and all swim distances (Morgan et al., 1987; Morouco et al., 2008).

Therefore, the purpose of this study was to examine the effect of training load on psychological and performance variables of collegiate female swimmers across a competitive season. The results may determine possible signs of overtraining as well as timing of tapering phases that may be necessary during a season.

Methods

Participants

Nineteen apparently healthy female NCAA Division I swimmers volunteered for the study. All participants had been swimming competitively for at least 5 years. Participants were instructed that they could withdraw from the study at any time without athletic penalty. All participants provided written consent in accordance with university ethical review committee guidelines. All participants were cleared to participate in athletics by the university athletic training staff prior to the study. Due to injuries, only 16 of the 19 participants completed all six trials.

Design

There is little research examining the effect of a full competitive season on performance and perceived stress and recovery in collegiate female swimmers. The aim of this prospective observational study was to identify different training load groups and changes across time in performance and perceived stress and recovery. To assess performance participants completed a tethered swim test to determine mean force output and filled out a perceived stress and recovery questionnaire monthly throughout the season. Differences in the training load between groups was based on the yardage swam (external load) by subjects and their reported session Rated Perceived Exertion (internal load) (Borg, 1998).

Measures

Tethered Swimming Device: The equipment used for this device included a Futek™ tension and compression load cell, Model LSB302 (Irvine, CA) firmly attached to the starting platform of the first lane of the pool and connected to a BioPac™ system, Model MP36RWSW (Aero Camino Goleta, CA) by a BioPac™ custom interface that was calibrated by the manufacturer. Connected to the load cell was a 10-meter non-elastic tether with a swim belt attached to the end. Prior to data collection the force sampling system was tested utilizing a series of known weights. Data was sampled at 1000 Hz.

The protocol for the tethered swimming test, previously described in the literature in detail (Morouco, 2009), began with subjects completing a 1000-1200 yard warm up. The subject then put on the swim belt and adopted a horizontal position in the water with the cable fully extended. Data collection was started by a hand signal, followed by an auditory signal for the participant to begin a 30s maximal freestyle tethered swimming test (Morouco, 2009). The same auditory signal was used to end the test. The mean of 20 seconds representing the middle ±10s was used to calculate F_{mean}.

Recovery Stress Questionnaire for Sport-76: The RESTQ-Sport is a multidimensional questionnaire that evaluates the recovery and stress state of an athlete. This questionnaire is based on the Profile of Mood State (POMS) and developed specifically for the athletic population (Morgan et al., 1987). There are 19 sub-scales, including 12 general scales and 7 sport specific scales measuring perceived stress and recovery state of the athlete within the last 3 days. For most items, the greater the rating, the more the athlete felt they were able to recover. Several items were reverse-scored, however, such as the questions referring to their sleep. The RESTQ-Sport was administered monthly (including a pre and post-season measure) after a full day of rest prior to the first morning workout of the week (Kellmann & Kallus, 2001). Total Recovery-Stress State (TRSS) is defined as the difference between the mean scores of the recovery and the mean scores of the stress scales (Kellmann & Kallus, 2001).

Training Load Groups: At the conclusion of data collection Total Training Load (TTL) was calculated utilizing session RPE and yardage swam (Wallace et al., 2008). RPE is a scale used to identify a participant's believed rate of exertion. The scale ranges from no exertion at all to maximal exertion and is selected by the participant himself (Borg, 1998). First, the Daily Internal Training Load was calculated by multiplying Session-RPE and the meters completed at that training session. This calculation was repeated for every training session throughout the course of the season. All Daily Internal Training Loads were summed to determine the TTL. The participants were divided into thirds according to their TTL score by identifying natural breaks in the data, with the top third (n=6) representing the "high training load group," the middle third (n=7) representing the "middle training load group," and the bottom third (n=6) representing the "low training load group." These groups were designed to acknowledge the fact that a swimming team is comprised of sprint, mid-distance, and long-distance swimmers, but the overall yardage swam did not have a significant different among groups.

Statistical Analysis

Data analysis was performed using SPSS 14.0 for Windows. The following variables were analyzed using repeated measures ANOVA: mean force (F_{mean}), and total recovery stress score (TRSS). The ANOVAs were checked for sphericity using Mauchly's test. Variable contrasts were examined using repeated contrasts. An alpha level of ($p \leq 0.05$) was considered significant for all analyses.

Results

Training Load*:* Swimming volume (meters) completed during each training session resulted in an average weekly total (30837.59m ± 9170.13m) as well as a season total (678427.04m ± 26468.61m). TTL was calculated, resulting in a number representing the sum of all session RPE scores and mean total internal training load (3817145 ± 326819.70). Based on the participants TTL, the three training load groups were established (High, n=6; Middle, n=7; Low, n=6).

Tethered Swimming Test*:* Individuals not completing all 6 trials (one from each of the three TTL groups) were removed from the analysis of F_{mean}. Results revealed no interaction between groups according to F_{mean} ($p=0.531$). Furthermore, no group effect was observed ($p = 0.792$). However, there was a significant time effect across the season ($p = 0.004$) for F_{mean}. Repeated contrasts revealed significant differences between Trial 1 and Trial 2 ($p = 0.004$; ES=0.40), and between Trial 3 and Trial 4 ($p = 0.017$; ES= -0.14). Descriptive statistics revealed that between Trial 1 (84.39N ± 13.58N) and Trial 2 (78.90N ± 15.06N) there was a significant decrease in F_{mean}, whereas between Trial 3 (75.62N ± 18.79N) and Trial 4 (78.28N ± 18.65N) there was a significant increase in F_{mean}.

Corresponding with the collection points of F_{mean}, further analysis revealed significant changes in the meters completed (Figure 1) with significant differences between Trial 1 and Trial 2 ($p <0.001$; ES= -2.10), between Trial 4 and Trial 5 ($p <0.001$; ES= -0.78), and between Trial 5 and Trial 6 ($p<0.001$; ES= 1.05). Descriptive statistics revealed that that there were significant increases between Trial 1 (18182.12m ± 5560.57m) and Trial 2 (29903.29m ± 4013.88m) as well as between Trial 4 (29234.33m ± 14133.38m) and Trial 5 (40324.08m ± 11168.23m). Finally, between Trial 5 and Trial 6 (28565.37m ± 2409.57m) there was a significant decrease in meters completed.

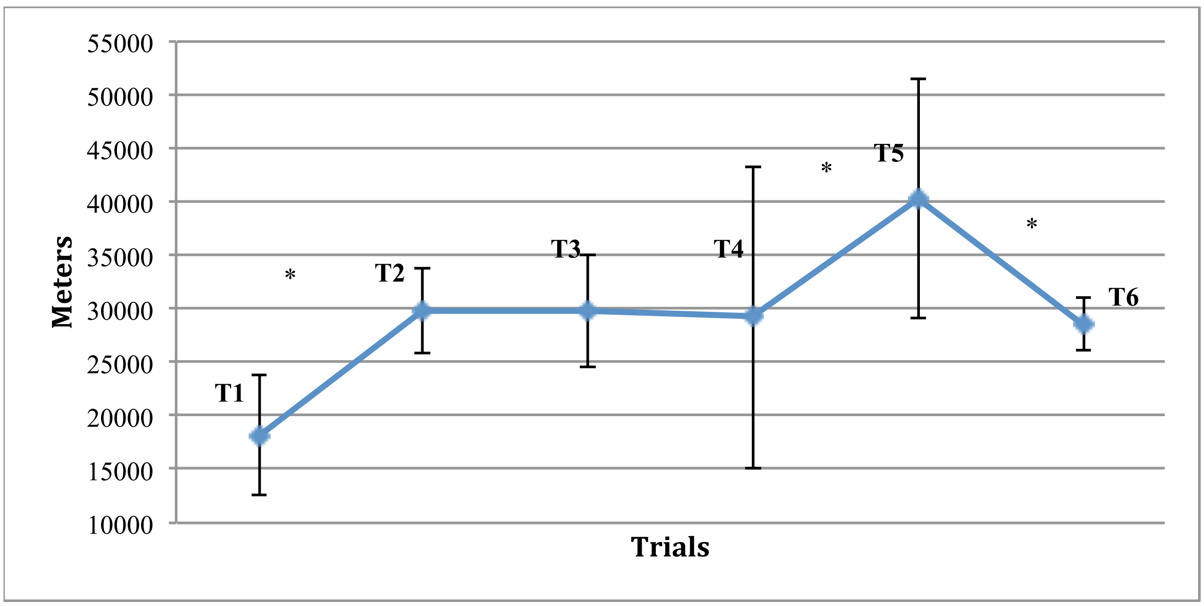

Figure 1. Average Weekly Team Meters Completed Prior to Tethered Swim Test (n=19). (*)= Significant difference (p<.05) from previous trial.

Recovery Stress Questionnaire for Athletes-76*:* Results revealed no significant interaction between groups for TRSS. Furthermore, no group effect was observed ($p=0.79$). However, there was a significant time effect across the season ($p<0.001$) for TRSS. Contrasts revealed that there was a significant difference between Trial 1 and Trial 2 ($p = 0.006$; ES= 0.55), Trial 2 and Trial 3 ($p=0.05$; ES= 0.43), Trial 3 and Trial 4 ($p<0.001$; ES= -0.65), and between Trial 5 and Trial 6 ($p<0.001$; ES= -1.41). Descriptive statistics showed that between Trial 1 (9.72 ±13.83) and Trial 2 (2.29 ±12.89), and between Trial 2 and Trial 3 (-3.37 ±13.65), there were significant decreases. However, from Trial 3 to Trial 4 (5.57 ±14.80), and from Trial 5 (2.72

±12.67) to Trial 6 (20.68 ±10.86), there were also significant increases in TRSS (Figure 2).

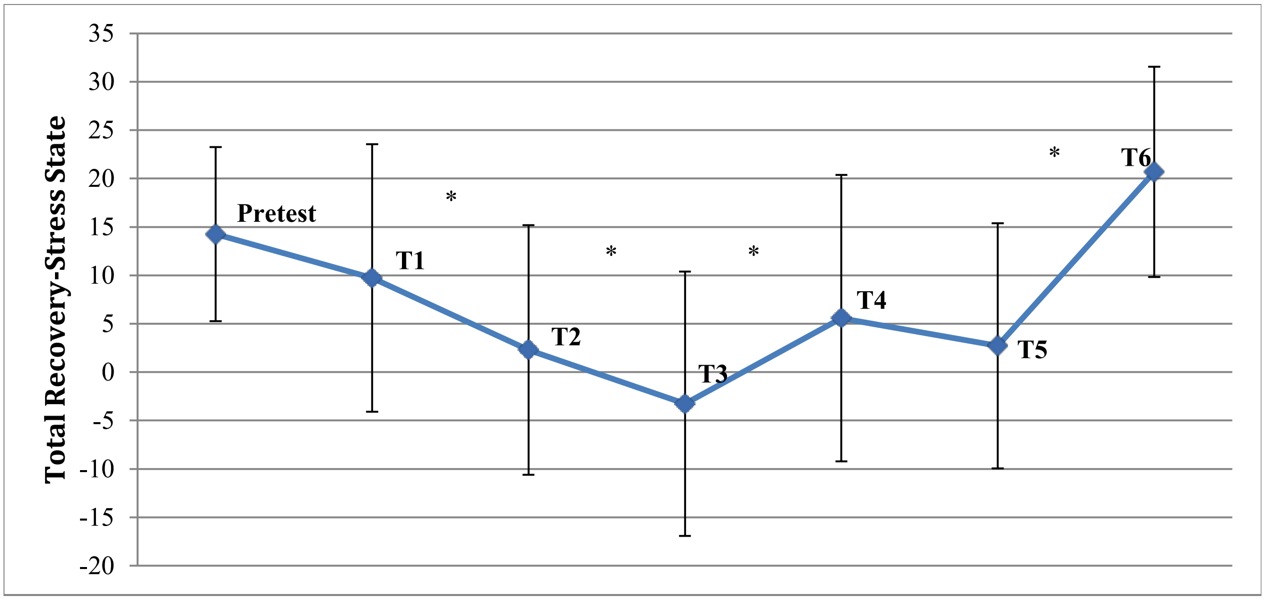

Figure 2. Average Total Recovery-Stress State (n=19). (*)= Significant difference (p<.05) from previous trial.

TRSS and meters completed followed similar patterns where increases in meters occurred concurrently with decreases in TRSS and vice versa. As shown in Figure 3, analysis identified significant changes in the meters completed in the weeks prior to the Trial, including significant differences between Trial 1 and Trial 2 (p<0.001; ES= -2.10), between Trial 4 and Trial 5 (p<0.001; ES= -0.64), and between Trial 5 and Trial 6 (p<0.001; ES= 0.88).

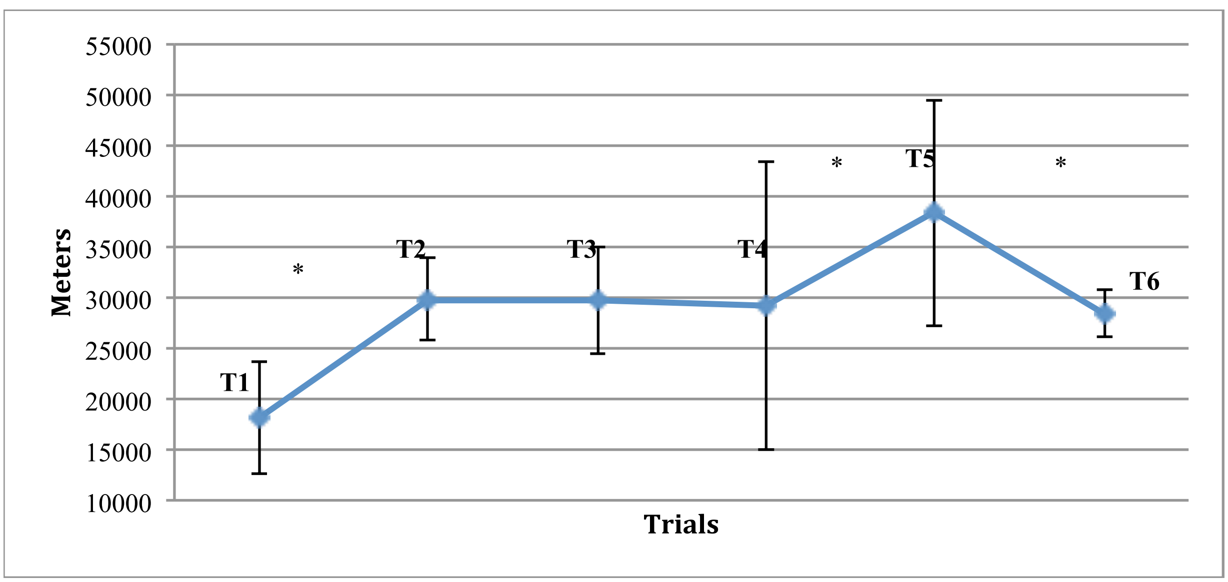

Figure 3. Average Weekly Team Meters Completed Prior to RESTQ-Sport Trial. (*)= Significant difference (p<.05) from previous trial.

Training Load*:* Descriptive statistics revealed that between Trial 1(18182.12m ±5560.57m) and Trial 2 (29903.29m ± 4013.88m), and also Trial 4 (29234.33m ± 14133.38m) and Trial 5 (38386.35m ± 11097.71m), there were significant increases in meters completed. Finally, between Trial 5 and Trial 6 (28521.26m ± 2309.53m) there was a significant decrease in meters completed. The pre-test was not included in the analysis because no meters had been completed prior to the Trial.

DISCUSSION

The purpose of the current study investigated the effect of training load on psychological and performance variables of swimmers across a competitive season. Results obtained suggest that, although there were no significant differences between the training load groups for the aforementioned variables, there were significant changes across time that aligns with periods of heavy training and periods of relative rest.

Tethered Swimming Test: Mean force data ranged from 47.8N-119.9N and is consistent with previous studies (Dopsaj et al., 2003; Morouco, 2009; Morouco et al., 2008). Results of the tethered swimming test did not reveal significant differences between training groups for F_{mean} across the competitive season. Although no significant interaction was found, data indicated significant time effects across the season for the whole team. The temporary decreases and increases in performance, represented by F_{mean}, correspond to the increases and decreases in meters swam. Results indicated a significant decrease in F_{mean} between T1 and T2 with significant increase in average weekly meters swam. A significant increase in F_{mean} was observed between T3 and T4. Although no statistical significance was found with corresponding meters completed, it can be suggested that the significant increase in performance could be attributed to the rest the athletes may have received while on the University's Thanksgiving break, during which training was decreased. Hooper and colleagues (1998) reported significant increases in peak tethered swimming force after 2 weeks of decreased training volume and intensity. Kenttä & Hassmén (1998) propose the increase in performance followed by a short period of recovery to be a super-compensation response. The results from similar studies and the current study support the inverse relationship between training load and performance. These results also support the importance of sufficient training stimulations paired with recovery to maximize performance, which follows the basic understanding of training stress and recovery (Kreider, Fry, & O'Toole, 1998).

Recovery Stress Questionnaire for Athletes-76: Results obtained from the RESTQ-76, represented by the TRSS did not show significant differences in training load groups across the competitive season, but it showed a significant time effect similar to the results of the tethered swimming test. The temporary changes in TRSS may be a result of the changes in swimming volume as well as periods of rest.

A significant decrease in TRSS was observed between T1 and T2 and average weekly meters swam significantly increased from T1 to T2. The significant decrease in TRSS is consistent with previous studies, confirming that an increase in training volume induces a significant increase in perceived stress and decrease in perceived recovery (Budgett, 1990; Jurimae et al., 2004). In two similar studies (Gonzalez-Boto et al, 2008; Kellmann et al., 2001), RESTQ-Sport-76 was able to show significant changes concurrently with training load, such that when training volume was increased, TRSS decreased. O'Connor and associates (1989) reported significant increases in tension, depression, anger, vigor, fatigue and global mood using the POMS correlated to an increase in daily training from 2,000m to 12,000m over a 6-month period. The results from this study and the current study further demonstrate the inverse relationship between perceived stress/recovery state and training volume.

A significant increase in TRSS was observed between T3 and T4, although average weekly meters swam was not significantly different between trials. In preparation for a mid-season taper of training load there was a 3d rest period, which preceded T4 data collection. It appears that the short-term rest period had a significant and positive impact on the athlete's perceived recovery-stress state. These findings are consistent with the literature suggesting that tapering, or allowing the athlete a short period of rest and recovery, regularly throughout the season is beneficial (Budgett, 1990). Similarly, the final data collection for the RESTQ-Sport 76 took place prior to the conference championship following a month long, progressive decrease in swimming volume. Resultant data revealed a significant increase in TRSS between T5 and T6. There is a significant decrease in average weekly meters swam between T5 and T6, which may explain this significant increase in TRSS. Similar to the findings of Budgett (2000) and O'Connor (2007), reductions in training consistently reduce feelings of fatigue as well as increased feelings of energy.

The results of this study suggest that evaluation of an athlete's perceived recovery-stress state is important when monitoring athletes throughout a season in order to prevent symptoms of overtraining and underperformance. Monitoring of perceived stress- recovery state on a regular basis can be an inexpensive, quick, and valuable tool which can improve physical performance and psychological state of athletes (Gonzalez-Boto et al., 2008; Kellmann & Kallus, 2001).

Overall, results indicate that, although there were no statistically significant differences between training load groups for the performance and psychological variables, there were significant changes across time for both variables. Furthermore, the significant changes detected for both performance and psychological variables corresponded with significant changes in weekly training meters completed, revealing an inverse relationship between meters and the aforementioned variables. The results of the current study demonstrate the intricate relationship between training load, performance, perceived stress, and recovery during a competitive collegiate season in collegiate female division I swimmers.

Practical Applications

The intentions of this study were to examine the relationships between training load and subsequent performance and perceived stress-recovery states across a competitive season. For coaches and athletes, the results of the current study suggest training stress-recovery state along with measures of performance should be monitored in order to help ensure optimal training adaptation. This information can then be used in future training decisions to hopefully avoid symptoms of overtraining and possible overuse injuries. Monitoring this information can help coaches utilize tapering phases if they feel their athletes are experiencing burnout. Constant monitoring of athletes in such a way can provide optimal training volumes and potentially yield the highest possible performances. From a practical perspective, the measures used in this study are minimally invasive and provide immediate results that can be quickly disseminated to coaches and athletes. The Recovery Stress Questionnaire for Athletes-76 User manual contains software that allows coaches to establish profiles of their athletes over time allowing for a time efficient method to monitor them across a season.

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