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Title: Psychodiagnostics: Classification of the yips phenomenon based on musician's dystonia

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ABSTRACT

Purpose: Similar to musician's focal dystonia a task-specific phenomenon, known as yips has also been reported in professional athletes. Yips is usually described as focal dystonia, or choking under pressure, or as lying on a continuum between both. Based on the common occupational conditions across musicians and athletes, the present exploratory study aimed to investigate whether musicians diagnosed with focal dystonia and golfers affected with yips, can be similarly sub-classified based on their psychological profiles.

Methods: Twenty healthy musicians, 20 musicians with focal dystonia, 20 healthy golfers and 20 yips-affected golfers went through a test battery including three psycho-diagnostic standardized questionnaires (the *Competitive Trait Anxiety Inventory,* the *Frost's Multidimensional Perfectionism Scale*, and the *Stress Coping Questionnaire*), measuring trait cognitive and somatic anxiety, perfectionistic tendencies and different stress coping strategies.

Results: Findings based on a clustering procedure suggest that similar to musician's dystonia, yips-affected golfers can be classified into those with and those without specific elevated perfectionistic, stress and anxiety traits. The roles of these different psychological profiles as possible triggering factors of the yips are discussed and compared to those of musician's dystonia.

Conclusion: The current study suggests that the yips phenomenon might cover a broader range of different subtypes of movement disturbances than those already suggested in the literature. Finally a theoretical model, which explains the role of the different triggering factors in the discrimination of the different subtypes, is suggested. A better classification and understanding of the different subtypes of yips could lead to a more accurate diagnosis and to the design of more individualized treatment intervention.

Keywords: yips-affected golfers; musician's dystonia; psycho-diagnostics; cluster analysis; classification; triggering factors

INTRODUCTION

Task-specific focal dystonias often affect individuals in professions where highly trained fine motor skills are required (1, for a review). Insights concerning the aetiology of task-specific focal dystonias have previously been obtained by comparing focal dystonia patients from different professions, for instance musicians and writers (2). Similarly, the current study attempts to examine and compare the psychological backgrounds of musicians diagnosed with focal dystonia and golfers affected with yips. Focal dystonia in musicians or musician's dystonia is characterized by muscular incoordination and loss of voluntary motor control while playing a musical instrument. It usually affects one, two or more fingers of the more heavily used hand (3). As a result, irregularities in timing, unevenness in movements and slowing down of fast musical passages lead to a deterioration in the overall performance quality (3). Yips is a similar movement disorder and is defined as: "a psycho-neuromuscular impediment affecting the execution of fine motor skills during sporting performance" (4). In golfers it is mainly characterized by twisting or jerking of the lower arm (and wrist) either before or during ball contact. It mainly occurs in relatively short-distance putting and usually leads to missing the putt (4-6). Dystonic musicians (DM) and yips-affected golfers (YG) have involuntary movement and task-specificity in common. Task-specificity indicates that symptoms occur primarily while playing the musical instrument or while putting with the golf club. Furthermore, both occupations require an extensive amount of practicing and the execution of repetitive fine-motor temporospatially coordinated movements under high-pressure conditions (7).

Although there are commonalities between the two types of movement disorders, differences also exist. For instance, musician's dystonia is characterized by a prolonged flexion or extension of the affected body part (finger[s]). In contrast, golfer's yips is described more as a twisting or dystonic tremor-like movement. Furthermore, the prevalence of musician's dystonia is estimated to be approximately 1% (3) and is much lower than the reported prevalence rates of yips, which range from 17 to 48 % (5,6,8). Finally, focal dystonia in musicians affects professional or experienced players (3). While yips-affected golfers also usually operate at a higher skill-level (9), a few recent studies have suggested the existence of yips symptoms in beginners (8,10,11,12).

The aetiology of both task-specific movement disorders is multifactorial and still not fully understood. Pathophysiological findings on focal dystonia have indicated abnormal inhibitory mechanisms, dysfunction of the sensorimotor system, abnormalities within the basal ganglia, and abnormal brain plasticity (1,3). Concerning the aetiology of golfer's yips, different studies have classified this phenomenon either as focal dystonia (an organic problem), or 'choking under pressure' (a psychological problem), or on a continuum between both (6,9,13-15,16). Choking under pressure describes the occurrence of a significant drop in performance due to a perceived mismatch between situational demands and the athlete's resources (e.g. due to increased performance anxiety) (17). Where on this continuum the yips phenomenon sits remains a matter of debate.

With respect to psychological investigations, findings in various forms of focal dystonia have clearly revealed that the condition in a considerable proportion of patients is related to psychological comorbidities. Review studies have concluded that those comorbidities were not a psychoreactive effect but pre-existed the dystonia onset (18). Concerning DM, studies

have found associations with higher levels of anxiety, perfectionism, neuroticism, social and/or other specific phobias (3,19). Recently, a more detailed investigation by Ioannou and Altenmüller (20) revealed that DM can be sub-classified into those with and those without psychological vulnerabilities, based mainly on contrasting levels of chronic perfectionism, anxiety and stress-coping styles. Further studies comparing the different subtypes have indicated that in addition to sensorimotor triggering factors (e.g. workload, handedness, instrument, controllability of actions etc.), psychological comorbidity should be considered as an additional triggering factor, which could significantly contribute to the manifestation of focal dystonia (21,22). However, increased levels of stress and anxieties related to music performance have been also reported in many healthy musicians, a condition known as music performance anxiety. Several studies have shown that musicians with performance anxiety often experience motor deterioration (23-25) or muscular stiffness, which could in turn disrupt fine motor coordination (26).

Studies focusing on yips' psychological profiles remain highly contradictory (4). Some studies have found psychological features distinguishing between affected and unaffected athletes. For instance, yips-affected athletes would experience higher levels of perfectionism (27) and tend to consciously control their movements or to think obsessively about the problem (5). Furthermore Philippen and Lobinger (12) reported that about two thirds of YG primarily focus internally or on potential mistakes while stroking and Stinear et al. (16) reported alteration of the state anxiety between relaxed and stressed conditions, which was associated with changes in putting accuracy. In contrast, other studies could not confirm the existence of distinguishing psychological profiles (9,28) or any association with reinvestment (29) between yips-affected athletes and controls. The ambiguity may be due to different methodological approaches, such as the usage of different golfer's yips criteria (28), or

because of a heterogeneity (e.g. different subtypes grouped together) among the yips-affected athletes (13). Only a few studies have suggested the existence of different subtypes of YG, for instance into those who primarily report movement-related symptoms versus those with anxiety-related symptoms (6,9,16) or those who may experiencing both symptom subtypes (4). There is therefore a necessity for further investigation of the psychological triggering factors to the manifestation of yips, and a clarification of the different possible subtypes.

The current open-design exploratory study aimed to investigate and compare the psychological profiles of DM and YG. Based on the nature of both occupations, which include high level of performance under stressful and demanding endo- and exogenous conditions, sub-characteristics related to trait anxiety, perfectionism and stress coping strategies were examined (20,28). The yips phenomenon, which remains under-investigated in comparison to focal dystonia, seems to cover a range of still-unidentified subtypes, as well as some already suggested in the literature. We expected that similar to DM (20,22), YG would be sub-classified into different psychological profiles. As a final goal we attempted to explain the role of those different psychological profiles by suggesting a broader classification of yips in comparison to previous evidence and reports. We hope that the comparison between the two similar movement disorders will provide further understanding of the yips phenomenon and its possible subtypes.

METHODS

Participants

Eighty participants, (20 healthy musicians [HM], 20 DM, 20 healthy golfers [HG] and 20 YG) filled out a psycho-diagnostic test battery. HM were randomly recruited via published announcements and were either freelancers or members of orchestras, music schools or

universities. DM were all diagnosed with focal hand dystonia by the last author (EA) and were selected from the outpatient clinic of Music Physiology and Musicians' Medicine after setting exclusion criteria (i.e. participants with any neurological [e.g. secondary dystonia, tremor] or psychiatric [e.g. depression] disturbances). Patients selected in this way were contacted in random order and asked for their willingness to participate. Likewise, HG and YG were both randomly recruited from local golf clubs (also via published announcements) and from the database of the Institute of Psychology (same procedure as above). All golfers were re-tested and assigned as yips-affected and non-affected by the second author (MK). YG were mainly characterized by involuntary movements such as twisting or jerking of the lower arm during the one-handed putting test (28). Further characteristics can be seen in Table 1. All participants were informed of the requirements of the investigation and all provided informed consent before testing commenced. The protocol was conducted in accordance with the declaration of Helsinki and was approved by ethics committee of the board of the German Association of Psychology.

Instruments

The *Competitive Trait Anxiety Inventory* (CTAI) (GER: Wettkampf-Angst-Inventar Trait (30)), which is widely used in sport science, was used to assess trait anxiety before performance/competition. This psycho-diagnostic instrument has also been used in the past to assess competitive trait anxiety in musicians (20,22). CTAI assesses trait anxiety in three different components: "somatic anxiety" (e.g. *"Before competition I feel nervous"*), "self-doubt concern" (e.g. *"Before competition I worry about failing under pressure"*), and "concentration problems" (e.g. *"Before competition I am prone to distractions"*). All subscales consist of four items each and are answered on a 4-point scale ranging from 1 *"not at all"* to 4 *"very much"*. As suggested by the authors of the CTAI, the third subscale was

176 excluded from the analysis due to its low reliability (30). The reported Cronbach's alpha
177 value for the "somatic anxiety" subscale is .81 and for the "self-doubt concern" .83 (30).
178
179 Perfectionism was assessed with the German version of the *Frost's Multidimensional*
180 *Perfectionism Scale* (FMPS) (GER: Mehrdimensionale Perfektionismus Skala von Frost),
181 (31). FMPS consists of 35 different items that form six different subscales: "concern over
182 mistakes", "personal standards", "parental expectations", "parental criticism", "doubts about
183 actions" and "organisation". Cronbach's alpha values for the six subscales range from .70 to
184 .90. The participants had to rate each item on a 6-point scale from 1 *"does not apply at all"*
185 to 6 *"applies very well"*.
186
187 Stress coping strategies were obtained via the short form of the German *Stress Coping*
188 *Questionnaire* (SCQ) (GER: Stressverarbeitungsfragebogen), (32), which mainly examines
189 positive and negative coping stress strategies. Positive coping strategies include the subscales
190 "play down", "guilt denial", "distraction", "substitutional satisfaction", "situation control",
191 "reaction control" and "positive self-instruction". Negative coping strategies include the
192 subscales "flight tendency", "mental perseveration", "resignation" and "self-incrimination".
193 Finally two more neither positive nor negative strategies, "need for social support" and
194 "active avoidance" are also included. The internal consistency (α) of the all the subscales
195 ranges between .77 and .94. The participants had to imagine being in a stressful situation and
196 estimate on a 5-point scale from 0 *"not at all"* to 4 *"most likely"* to which degree a statement
197 applied to their own behaviour (total number of items 78). Finally, demographic,
198 occupational and movement disorder information were also collected.
199
200 ***Statistical analysis***

I. Group differences: A multivariate analysis (MANOVA) was used to examine possible group differences (HM vs. DM vs. HG vs. YG) on the 21 different subscales which derive from the three psycho-diagnostic questionnaires. An additional two-way MANOVA with fixed factors of "occupation" (golfers vs. musicians) and "disorder" (affected vs. non-affected) was also conducted in order to examine a possible interaction effect between the two factors. Due to the fact that no group differences were found between the four groups (apart from on two subscales) and no interaction effect was found between "occupation" and "disorder" a more detailed data exploration was conducted.

II. Cluster analysis: Assuming that no group differences existed, all participants were grouped together and all 19 subscales were used as dependent variables. A hierarchical procedure was then applied in order to estimate the x number of clusters (33). Subsequently a *K*-means analysis was performed in order to classify all participants into those x clusters. In order to estimate which dependent variables (subscales) contributed the most to the classification of participants into clusters, Mann-Whitney U tests were used. Finally the proportions, firstly between all musicians (patients and controls) vs. all golfers (patients and controls) and secondly between HM vs. DM vs. HG vs. YG, were calculated within each cluster, and tested by a chi-square test for significant frequency differences.

Point-biserial correlations were used to estimate effects of age, years of experience and cumulative hours of practicing, between clusters for musicians and golfers respectively. A significance level of $p < .05$ was used and Bonferroni corrections were applied in order to prevent inflated type I error. Data analyses were performed in IBM SPSS Statistics software package (version 24) and R (version 3.4.2).

RESULTS

Using Pillai's trace on all 21 subscales indicated a marginally significant psychological group difference, $V = .993$, $F(63, 174) = 1.37$, $p = .058$, $\eta_p^2 = .331$. Follow-up univariate ANOVAs (p accepted at $< .05/21_{subscales} = .00238$) were significant only for the subscales, "play down": $F(3, 76) = 5.67$, $p = .001$, $\eta_p^2 = .183$, and "resignation": $F(3, 76) = 5.45$, $p = .002$, $\eta_p^2 = 177$. Bonferroni post-hoc tests revealed significant differences between DM vs. HG ($p = .001$) for the "play down" subscale, and between DM vs. HG ($p = .002$) and DM vs. YG ($p = .021$) for the "resignation" subscale (Table 2).

A two-way MANOVA with fixed factors "occupation" (golfers vs. musicians) and "disorder" (affected vs. non-affected) indicated only an effect for occupation, $V = .433$, $F(21, 56) = 2.04$, $p = .018$, $\eta_p^2 = .433$. Neither a disorder effect ($V = .323$, $F(21, 56) = 1.27$, $p > .05$, $\eta_p^2 = .233$) nor an interaction effect between the two factors ($V = .286$, $F(21, 56) = 1.07$, $p > .05$, $\eta_p^2 = .286$) were observed. Follow-up univariate ANOVAs (p accepted at $< .05/21_{subscales} = .00238$) on the occupation effect were significant only for the "play down" subscale: $F(1, 76) = 10.97$, $p = .001$, $\eta_p^2 = .126$ with golfers showing a slightly higher score (1.9 ± 0.1 [M ± SE]) than musicians (1.4 ± 0.1 [M ± SE]).

Assuming that all four groups share similar psychological profiles due to a general lack of group differences, the 19 subscales without significant differences (excluding "play down" and "resignation" subscales) were used as single variables in the following clustering procedure. It was first established that none of the 19 variables (subscales) showed any substantial collinearity with any of the others: all correlations: $-.31 \leq r \leq .71$ (Pearson). Therefore all values were standardized into z-scores, since subscale evaluations were performed on different Likert scales. A hierarchical clustering analysis (Ward's method -

Squared Euclidean distance) indicated the classification of all 80 participants into two distinct clusters (see Dendrogram, Supplemental Digital Content 1). Different clustering procedures, algorithms and distance measures revealed similar clustering patterns, indicating the stability of the results. Finally a *K*-means analysis, based on two clusters, classified all participants. Reliability, which was tested by a cross-tabulation percentage agreement between two randomly divided subsamples (split-half) of the original data, indicated a Rand index of .49, and an Adjusted Rand Index of .02 (34).

Due to unequal group sizes of the resulting clusters and the non-normally distributed data in some variables (Shapiro-Wilk < .05), a follow-up Mann-Whitney U tests between the two clusters indicated that 13 out of 20 variables (subscales) functioned as primary contributors to the classification of the participants into two clusters (*p* values were accepted after a Bonferroni correction at $< .05/19_{subscales} = .0026$). These characteristics were: "doubts about actions", "concern over mistakes", "flight tendency", "parental criticism", "parental expectations", "active avoidance", "mental perseveration", "substitutional satisfaction", "self-incrimination", "personal standards", "somatic anxiety", "need for social support" and "self-doubt concern" (Figure 1). According to the classification of all participants into those two profiles, cluster 1 (representing participants with elevated scores of the above characteristics, $n = 46$) was labelled as "High tendency to Perfectionism, Anxiety and - inability to cope with - Stress" (HPAS) profile, and cluster 2 (representing participants with contrasting scores, $n = 34$) was labelled as "No tendency to Perfectionism, Anxiety and - inability to cope with - Stress" (NPAS) profile.

The association between the two clusters and the two occupations (musicians and golfers) revealed a significant difference: χ^2 (1) = 7.37, $p = .007$ (also Fischer's exact: $p = .012$).

Cluster 1 (HPAS) was mostly represented by musicians whereas cluster 2 (NPAS) was mostly represented by golfers. Finally, no significant association (2 x 4) was found between the two clusters and the proportion of HM, DM, HG and YG, χ^2 (3) = 7.57 p > .05 (Table 3). No differences between HPAS and NPAS clusters for DM and YG respectively were found concerning age, age when started playing, years and cumulative hours of experience, onset age, years of experience until onset, or level of expertise.

Due to differences in age, years of experience and cumulative hours of practicing between musicians and golfers, a point-biserial correlation was conducted in order to detect whether these three variables had any effect on the classification of musicians and golfers respectively to the two clusters (HPAS and NPAS). Results revealed that the classification of musicians into HPAS and NPAS was not significantly related to age, r_{pb} = .049, p >.05, years of experience, r_{pb} = .023, p >.05 or cumulative hours of practicing, r_{pb} = .088, p >.05. Hence, of the variability in the classification of musicians into two clusters, age accounted for (R^2 = $(.049)^2$ = .0024) 0.2%, years of experience for 0.1% and cumulative hours of practicing for 1%. Likewise, the classification of golfers in HPAS and NPAS was not significantly related to age, r_{pb} = .269, p >.05, years of experience, r_{pb} = .142, p >.05 or cumulative hours of practicing, r_{pb} = -.080, p >.05. Age accounted for 7%, years of experience for 2%, and cumulative hours of practicing for 1% of the variability in the classification of golfers into clusters. Finally, in order to examine (indirect) whether any psychological trait (subscale) was a psycho-reactive effect (i.e. due to the onset of the motor disturbances) all subscales were correlated with the number of years after onset. Results indicated no significant correlations for DM whereas for the YG only one perfectionistic feature ("parental criticism": r_s = .573, p = < .01), one neutral ("active avoidance": r_s = .638, p = < .01) and two negative coping

styles, ("flight tendency": r_s = .568, p = < .01; "resignation": r_s = .584, p = < .01) indicated significant correlations.

DISCUSSION

The current study revealed that all musicians and golfers (patients and healthy ones respectively) could be sub-classified into two different subgroups characterized by contrasting psychological profiles. The role of these different subtypes, as they relate to previously suggested triggering factors, are discussed and compared across yips and musician's dystonia. Finally a more refined classification of the yips is suggested, which remains to be confirmed by further electrophysiological examinations.

Multiple comparisons between groups (HM vs. DM vs. HG vs. YG) revealed no psychological differences (20,28). Following studies suggesting that focal dystonia patients (18,20) and yips-affected athletes are characterized by psychological heterogeneity (4,6,16), a clustering analysis was conducted. Findings indeed indicated the existence of two contrasting psychological profiles. Classification of participants into those two profiles was based on either high levels (HPAS) or low levels (NPAS) of specific perfectionistic traits, negative coping stress strategies and somatic and cognitive trait anxieties (for specific characteristics see Figure 1). Distributions of the two occupations within the two clusters indicated that the HPAS profile was mostly represented by musicians (63%) whereas the NPAS profile was mostly represented by golfers (68%) (see Table 3). The higher representation of the HPAS profile by musicians compared to golfers can probably be explained by the fact that the majority of the former group were professionals. For professional musicians, performing is a livelihood activity, whereas for golfers of such a high handicap this is not the case (mean handicap < 27; handicap is a numerical representation of golfers' playing ability with lower

numbers indicating better performance). However concerning the classification of each occupation individually into HPAS or NPAS, results indicated that proficiency (measured indirectly by "years of experience" and "cumulative hours or practicing") did not play a role at all. Finally, the greater representation of musicians and golfers in the HPAS and NPAS profiles, respectively, did not differ across patients and controls. That is, whether a participant was a patient or control did not affect the probability of their having an HPAS or NPAS profile, and this was the case for musicians and golfers (see Table 3). This emphasizes the existence of two different psychological subtypes for both occupations.

Different subtypes in YG and DM have been also reported in the past. For instance, Ioannou and Altenmüller (20) found that one in two DM was characterized by psychological comorbidities. Likewise, different subtypes of YG have also been described by Smith et al. (6), who distinguished a group of YG with more dystonia-related symptoms (Type I) and a group with symptoms related to performance anxiety or choking (Type II). Both subtypes were further evaluated by Stinear et al. (16) while performing under low- and high-pressure conditions. Besides the fact that the cognitive anxiety of those classed as Type I was increased during the stress condition, putting performance remained unaffected. On the other hand, Type II golfers (with anxiety-related symptoms) demonstrated reduced putting accuracy under stress. The authors suggested that Type I could be more related to impaired initiation during motor execution, a characteristic related to patients suffering from focal hand dystonia. In contrast, Type II (anxiety-related symptoms) was suggested to be associated with performance anxiety rather than with motor impairments of the central nervous system (9,16). The authors further indicated that there are also YG who experience both physical (dystonic) and psychological (choking) symptoms, with these golfers being labelled as Type III (4). However this subtype remains under-investigated.

The study by Stinear et al. (16) which seems to be the only experimental investigation comparing these different subtypes may be partially problematic. No objective assessments were used for participants' stress levels; instead the Competitive State Anxiety Inventory (CSAI-2) was used to evaluate state anxiety between low- and high-pressure conditions. This specific questionnaire has also been reported to have questionable validity and reliability (4,35). According to our knowledge there are no other experimental studies which investigated differences between the above suggested subtypes. An investigation similar to Stinear et al. (16) which compared the performance accuracy in DM under relax and stress conditions revealed no differences either for patients with or without psychological comorbidities (22). Moreover, and in contrast to Stinear et al. (16), the induced stress-level in DM was evaluated mainly by objective measurement (i.e. cortisol level and electrocardiography).

Apart from the limited evidence suggesting the classification of yips into Types I and II, the high prevalence of yips (17 to 48 %) seems to be at odds with that of musician's dystonia (1%) and that of other forms of primary focal dystonia (< .05%) (36). Specifically, Smith et al., (34) suggested that of 72 YG (2 were excluded), 40 were assigned as Type I (dystonia symptoms), 16 as Type II (psychological symptoms) and 14 as Types I and II (or according to Clarke et al. (4) as Type III). Likewise, Stinear et al. (16), who used only 9 non-affected golfers and 15 yips-affected golfers, concluded that 8 yips-affected golfers could be classified as Type I, and 7 as Type II. Given that the prevalence of yips has been reported to range between 17 and 48% (hypothetical mean = 32.5%) (5,6,8), the proportions of YG classified as Type I (dystonia symptoms) in the two studies described above (57% in Smith et al., (6), 53% in Stinear et al., (16)) would suggest a hypothetical prevalence of Type I yips-affected

golfers of 17-18%. This remains high with respect to the prevalence of focal dystonia more generally, and we believe that yips may cover a broader range of different subtypes mostly unrelated to focal dystonia.

We argue that Type II YG (with anxiety-related symptoms), who showed motor instabilities under stress situations may not be related to those DM with psychological comorbidities. Instead, Type III golfers who experience both physical (dystonic) and psychological (choking) symptoms (4,6) maybe closer to those DM with additional psychological comorbidities (22). However, Type II YG seem to be linked to those "healthy" (non-dystonic) musicians who experience motor disturbances due to elevated performance anxiety (23-26,37). Up to 60 % of active musicians have reported a negative impact of music performance anxiety on their performance (24). Wesner et al. (25) reported that 21% of healthy musicians were characterized by increased levels of music performance anxiety; 16.5% of them reported that music performance anxiety also impairs their musical performance. Other studies have further indicated that the level of anxiety increases when musicians are performing with a higher public status (37), or when solo compared to ensemble performance is required (23). A parallel can be drawn between findings indicating performance deterioration in musicians who suffer from music performance anxiety with studies revealing yips-symptoms exacerbation under stressful situations (5,6,16). However more experimental studies investigating yips symptoms under stress and relax conditions are needed in order to clarify the effect of stress and anxiety on the motor performance of yips.

The extent of these psychological traits as aggravating risk factors for the triggering of task-specific symptoms in musician's dystonia and yips remains poorly understood. A recent study which investigated a homogenous group of DM (only pianists) revealed that those

400 patients with elevated levels of anxiety, stress, and perfectionism had developed focal
401 dystonia about 10 to 15 years earlier than those patients without any psychological
402 comorbidity. It was suggested that those psychological behaviours (i.e. stress, anxiety and
403 perfectionism) in combination with other well-known sensorimotor triggering factors (see
404 next paragraph) could contribute as aggravating and accelerating risk factors to the
405 manifestation of focal dystonia (22). The pre-dystonic phase when minor and temporarily-
406 limited motor disturbances occur not only under stressful performance conditions but also,
407 for instance, while practicing, is known as *Dynamic Stereotype*, and is primarily linked to
408 musicians with elevated psychological traits, such as stress and perfectionism (14). A
409 prolongation of this situation which could lead to persistent dystonic movement patterns and
410 task-related loss of control, and therefore to focal dystonia (21). Therefore we suggest that
411 similar to DM, the HPAS-YG (yips-affected golfers with specific psychological tendencies)
412 may be described and further distinguished primarily into either (a) YG with performance
413 anxiety / choking (unrelated to dystonia), or to a lesser degree (b) YG with Dynamic
414 Stereotype (especially in cases where motor deterioration seems to also be present in non
415 stressful conditions), or to an even lesser degree (c) YG with focal dystonia accompanied by
416 psychological comorbidity.
417
418 The current study also detected a proportion of musicians and golfers who seem to have
419 developed their motor deficits in the absence of any stress, anxiety and perfectionism (i.e.
420 NPAS profile). Studies have already indicated that the deterioration of the fine motor control
421 of DM and YG, either with or without any psychological comorbidity, is mainly generated by
422 various common sensorimotor triggering factors. For instance, overuse (muscular fatigue),
423 demanding and intensive motor coordination, intensive repetitive patterns, gender (more
424 males are affected), handedness (right-handed players are mostly affected on the right hand

and left-handed players on the left), and specific biomechanics are among the most common triggering factors (3,6,9,10,13,16,21). Finally at least in musician's dystonia a genetic predisposition has also been reported. About 35% of DM have family members affected by other forms of dystonia (38). Therefore, NPAS-YG (yips-affected golfers with no psychological tendencies), or those classified as Type I (dystonia symptoms) according to Stinear et al. (16), could form another subtype of yips. However the prevalence of this subtype (17-18%) remains highly at odds with the prevalence of those DM with no additional psychological comorbidities (0.5%) (17).

The prevalence inconsistency between the two movement disorders may be further explained by a few recent studies which identified yips symptoms in novices, especially during putting with one hand (8,10-12). These findings emphasize the postulation that not all subtypes of the yips should be linked either to task-specific focal dystonia or to psychological comorbidities (e.g. choking) or to a combination of both. Marquardt (10) suggested that yips in novices derives not from a general movement disturbance, but instead from disruption to the executive movement mechanism in a specific context. Finally, more recently Marquardt et al. (11), also studying yips symptoms in novices, suggested that the only motor abnormal behavior was jerking while putting. The authors therefore classified yips-affected athletes as falling under either "yips in golfers" or "jerking in novices". Further studies are of course needed to clarify this classification but yips symptoms in amateurs highlight that further factors such as the level of expertise (e.g. handicap) and years of experience could also form crucial criteria for classifying yips-affected athletes (4,6). For instance, the high level of expertise (professional musicians) and the number of years of experience before onset (20-25 years) has been found to be associated with the manifestation of focal dystonia in musicians. Likewise, several studies drawing parallels between a subtype of YG and focal dystonia

450 included YG with a mean handicap below 7 and a mean of more than 25 years of experience
451 (6,13).
452
453 Summarizing the above discussion we suggest that golfers with movement disturbances can
454 be sub-classified to the following subgroups: a) to those with only "jerking symptoms in
455 novices", b) to those YG with "performance anxiety" (with psychological comorbidity mostly
456 related to "choking under pressure"), c) to those YG with "dynamic stereotype" (with
457 psychological comorbidity and more persistent motor disturbances), d) to those YG with
458 "focal dystonia accompanied by psychological comorbidity", and e) to those YG with "focal
459 dystonia in the absence of any psychological comorbidity". Although the suggested subtypes,
460 and the extent to which they overlap or lie on a continuum, remain to be further investigated
461 we suggest a schematic representation whereby the different subtypes can be diagnosed (or
462 further explored) based on the different triggering factors (psychological and sensorimotor)
463 which could initiate symptoms (Figure 2). The suggested subgroups, which aim to
464 complement the initial classification suggested by Smith et al. (6), could be used for further
465 exploration and explanation of the yips phenomenon in affected athletes.
466
467 The diagnostic parameters which could contribute significantly to a better distinction between
468 the above suggested subtypes of yips are: i) psychological comorbidity, ii) level of expertise,
469 dividing golfers into those with high (handicap < 5) and low (handicap > 20; (6), iii) years of
470 experience before onset (<1 vs. 20-30), iv) family-related history, v) exploration of the sports
471 biography / motor failure (e.g. whether motor symptoms occur under stressful, non-stressful,
472 or both conditions (10)), and vi) evaluation based not only on subjective but also on objective
473 measurements (e.g. kinematic screening test (8), physical / neurological phenomenological
474 examination, test of sensory trick, muscular co-contractions etc.). The inclusion of all the

different subtypes under the label of yips could also explain the high yips-prevalence in contrast to musician's dystonia (5,6,8). Our future plans focus on the evaluation and the (re)-adjustment of the above-suggested subtypes of yips (and musician's dystonia), using psychological, electrophysiological, and behavioral assessments. Investment in the classification of yips could enhance the diagnostic repertoire and promote studies focusing on more specific and tolerated treatments.

Finally we would like to underline a few limitations of the current investigation. First, the psycho-diagnostic evaluation was based on self-reports. A more reliable analysis should be preferably based on both subjective and objective measurements (9). Furthermore, musicians of the current study were mainly professional players (about two thirds) whereas the performance level of the recruited golfers was varied around the middle handicap range. Therefore, musicians and athletes of more similar professional levels should be examined. Additional characteristics such as cognitive patterns and the focus of attention, which have previously been suggested to be partly responsible for generating choking in at least a portion of yips-affected athletes, should also be examined (12,17,39). In addition, obsessive-compulsive behaviors, which have been highly detected in various forms of focal dystonia (18), remain to be comprehensively examined in both DM and YG. Finally, some investigations have suggested that psychological traits related to obsessional thinking and self-reported anxiety could be a psychoreactive phenomenon in YG (5,6,9). In contrast, perfectionism and trait anxiety investigated in the current study did not support any strong evidence of psycho-reaction, however more studies investigating a wider range of psychological aspects are needed to clarify this (18,20). Besides the challenges that motor and psychological behaviours may share common neurobiological networks (40), task-specific movement disorders remain rather unknown. Comparisons between similar

movement disorders may provide further insights, advancing understanding of the aetiological mechanisms behind them.

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CONFLICT OF INTEREST

The authors declare that they have no relationships with companies or manufactures who will benefit from the results of the present study. The results of the present study do not constitute endorsement by ACSM and are presented clearly, honestly and without fabrication, falsification, or inappropriate data manipulation.

REFERENCES

1. Torres-Russotto D, Perlmutter JS. Task-specific dystonias. A review. *Ann N Y Acad Sci* 2008;1142:179-199.
2. Rosenkranz K, Williamon A, Butler K, Cordivari C, Lees AJ, Rothwell JC. Pathophysiological differences between musician's dystonia and writer's cramp. *Brain* 2005;128(Pt 4):918-31.
3. Altenmüller E, Jabusch H-C. Focal hand dystonia in musicians: Phenomenology, aetiology, and psychological trigger factors. *J Hand Ther* 2009;22:144-155.

4. Clarke P, Sheffield D, Akehurst S. The yips in sport: A systematic review. *Int Rev Sport Exerc Psychol* 2015;8(1):156-184.
5. McDaniel KD, Cummings JL, Shain S. The yips: A focal dystonia of golfers. *Neurology* 1989;39:192-195.
6. Smith AM, Adler CH, Crews D, et al. The "yips" in golf: A continuum between a focal dystonia and choking. *Sports Med* 2003;33(1):13-31.
7. Ericsson KA, Krampe RT, Tesch-Römer C, The role of deliberate practice in the acquisition of expert performance. *Psychol Rev* 1993;100:363-406.
8. Klämpfl, MK, Philippen PB, Lobinger BH. Self-report vs. kinematic screening test: Prevalence, demographics, and sports biography of yips-affected golfers. *J Sports Sci* 2015;33(7):655-664.
9. Adler CH, Crews D, Kahol K, et al. Are the yips a task-specific dystonia or "golfer's cramp"? *Mov Disord* 2011;26:1993-1996.
10. Marquardt C, Strauss M, Hermsdörfer J. Putting "yips" and Jerking in golf novices. In: *International Journal of Golf Science*, 2016, 5(Suppl.), S1-S77. In: *Proceedings of the World Scientific Congress of Golf VII*; 2016 Jul 18-22: (Scotland). 2016, p S50-S51.
11. Marquardt C. The vicious circle involved in the development of the yips. *Int J Sports Sci Coach* 2009;4:67-78.
12. Philippen PB, Lobinger BH. Understanding yips in golf: Thoughts, feelings, and focus of attention in yips-affected golfers. *Sport Psychol* 2012;26:325-340.
13. Adler CH, Crews D, Hentz JG, Smith AM, Caviness JN. Abnormal co-contraction in yips-affected but not unaffected golfers: Evidence for focal dystonia. *Neurology* 2005;64:1813-1814.
14. Lobinger BH, Klämpfl MK, Altenmüller E. We are able, we intend, we act - but we

550 do not succeed: A theoretical framework for a better understanding of paradoxical
551 performance in sports. *J Clin Sport Psychol* 2014;8(4):357-377.
552 15. Masters R, Maxwell J. The theory of reinvestment. *Int Rev Sport Exerc Psychol*
553 2008;1:160-183.
554 16. Stinear CM, Coxon JP, Fleming MK, Lim VK, Prapavessis H, Byblow WD. The yips
555 in golf: Multimodal evidence for two subtypes. *Med Sci Sports Exerc* 2006;38:1980-
556 1989.
557 17. Hill DM, Hanton S, Matthews N, Fleming S. Choking in sport: A review. *Int Rev*
558 *Sport Exerc Psychol* 2010;3:24-39.
559 18. Zurowski M, McDonald WM, Fox S, Marsh L. Psychiatric comorbidities in dystonia:
560 Emerging concepts. *Mov Disord* 2013;28(7);914-920.
561 19. Enders L, Spector JT, Altenmüller E, Schmidt A, Klein C, Jabusch H-C. Musician's
562 dystonia and comorbid anxiety: Two sides of one coin? *Mov Disord* 2011;26(3):539-
563 542.
564 20. Ioannou CI, Altenmüller E. Psychological characteristics in musician's
565 dystonia: a new diagnostic classification. *Neuropsychologia* 2014;61:80-88.
566 21. Altenmüller E, Ioannou CI, Raab M, Lobinger B. Apollo's curse: Causes and cures of
567 motor failures in musicians: A proposal for a new classification. *Adv Exp Med Biol*
568 2014;826:161-178.
569 22. Ioannou CI, Furuya S, Altenmüller E. The impact of stress on motor performance in
570 skilled musicians suffering from focal dystonia: physiological and psychological
571 characteristics. *Neuropsychologia* 2016;85:226-236.
572 23. Brugués AO. Music performance anxiety--part 1. A review of its epidemiology. *Med*
573 *Probl Perform Art* 2011;26(2):102-105.

574 24. Fishbein M, Middlestadt SE, Ottati V, Straus S, Ellis A. Medical problems among
575 ICSOM musicians: overview of a national survey. *Med Probl Perform Art* 1988;3:1-
576 8.
577 25. Wesner RB, Noyes R, Davis TL. The occurrence of performance anxiety among
578 musicians. *J Affect Disord* 1990;18:177-185.
579 26. Yoshie M, Kudo K, Murakoshi T, Ohtsuki T. Music performance anxiety in skilled
580 pianists: effects of social-evaluative performance situation on subjective, autonomic,
581 and electromyographic reactions. *Exp Brain Res* 2009;*199*(2):117-126.
582 27. Roberts R, Rotheram M, Maynard I, Thomas O, Woodman, T. Perfectionism and the
583 "Yips": An initial investigation. *Sport Psychol* 2013;27:53-61.
584 28. Klämpfl MK, Lobinger BH, Raab M. How to detect the yips in golf. *Hum Mov Sci*
585 2013a;32(6):1270-1287.
586 29. Klämpfl MK, Lobinger BH, Raab M. Reinvestment - The Cause of the Yips? *PLoS*
587 *One* [Internet]. 2013b:8(12):e82470. doi:10.1371/journal.pone.0082470
588 30. Brand R, Ehrlenspiel F, Graf K. *Das Wettkampfangst-Inventar (WAI). Manual zur*
589 *komprehensiven Eingangsdiagnostik von Wettkampfangst, Wettkampfängstlichkeit*
590 *und Angstbewältigungsmodus im Sport. [The Competitive Anxiety Inventory (CAI).*
591 *Manual for comprehensive diagnostics of competition anxiety and anxiety*
592 *management in sports]*. Bonn (Germany): Bundesinstitut für Sportwissenschaft; 2009.
593 31. Altstötter-Gleich C, Bergemann N. Testgüte einer deutschsprachigen Version der
594 Mehrdimensionalen Perfektionismus-Skala von Frost, Marten, Lahart und Rosenblate
595 (MPS-F). [Test score of a German-language version of the multidimensional
596 perfectionism scale by Frost, Marten, Lahart and Rosenblate (FMPS)]. *Diagnostica*
597 2006;52:105-118.
598 32. Erdmann G, Janke W. *Stressverarbeitungsfragebogen (SVF). Stress, Stress-*

verarbeitung und ihre Erfassung durch ein mehrdimensionales Testsystem [Stress coping questionnaire (SCQ). Stress, stress processing and their detection by means of a multi-dimensional test system]. Göttingen: Hogrefe; 2008.

33. Punji G, Stewart DM. Cluster analysis in marketing research: review and suggestions for applications. *J Mark Res* 1983;20(2):134-148.
34. Hubert L, Arabie P. Comparing partitions. *J classification* 1985;2:193-218.
35. Cox RH, Martens MP, Russell WD. Measuring anxiety in athletics: The revised competitive state anxiety inventory-2. *J Sport Exerc Psychol* 2003;25:519-533.
36. Steeves TD, Day L, Dykeman J, Jette N, Pringsheim T. The prevalence of primary dystonia: a systematic review and meta-analysis. *Mov Disord* 2012;27(14):1789-1796.
37. Fehm L, Schmidt K. Performance anxiety in gifted adolescent musicians. *J Anxiety Disord* 2006;20(1):98-109.
38. Schmidt A, Jabusch HC, Altenmüller E, et al. Etiology of musician's dystonia: Familial or environmental? *Neurology* 2009;72(14):1248-1254.
39. Land WM, Franka C, Schacka T. The influence of attentional focus on the development of skill representation in a complex action. *Psychol Sport Exerc* 2014;15(1):30-38.
40. Ron MA. Primary focal dystonia--a disease of brain and mind: motor and psychiatric manifestations have a common neurobiological basis. *J Neurol Neurosurg Psychiatry* 2009;80(10):1059-1059.

Supplemental digital content 1: Dendrogram revised.tiff

Captions:

Figure 1. Final cluster centers of the principal (left to right) subscales which contributed to the classification of participants into HPAS (n = 46) and NPAS (n = 34) profiles (clusters). Abbreviations: HPAS = *High tendency to Perfectionism, Anxiety*

and - inability to cope with - Stress profile; NPAS = *No tendency to Perfectionism, Anxiety and - inability to cope with - Stress* profile. Error bars: ±1SE.

Figure 2. The above schematic representation suggests the classification of the yips phenomenon inspired by the comparison between dystonic musicians and yips-affected golfers. The different boxes (subtypes) are located according to severity (y-axis) and experience (x-axis). Finally, the contribution of the psychological and/or sensorimotor triggering factors to the different subtypes is also indicated. Subtype (A) indicates mainly jerking symptoms in novice golf players. Subtype (B) indicates motor disturbances due to stressful and demanding conditions. Subtype (C) indicates subjects with subtle but more persistent motor disturbances. Those subjects are also characterized by more persistent psychological traits (e.g. elevated stress, anxiety, perfectionism etc.). Subtype (D) indicates an accelerated (earlier in years) manifestation of dystonic cramps. Usually these patients come from the Dynamic Stereotype phase. Finally, subtype (E) indicates those individuals with an already manifested focal dystonia. This subtype represents subjects who develop dystonia either exclusively due to sensorimotor triggering factors, or due to psychological and sensorimotor triggering factors (i.e. Dynamic Stereotype). Subtypes (A) and (B) have so far been seen to be unrelated to focal dystonia. However, it remains unknown whether there is a continuum between these two subtypes and the absolute manifestation of dystonia.

Table 1. Participant characteristics

Parameter	HM	DM	HG	YG
Age: years (*M* ± *SD*)	39.7 ± 8.5	41.3 ± 8.5	51.3 ± 14.1	53.9 ± 13.9
Gender: (female / male) (*n*)	3 / 17	3 / 17	2 / 18	2 / 18
Handicap: (*M* ± *SD*)	-	-	33.5 ± 18.7	27.4 ± 17.5
Occupation: Professional / semi-professional or music student / amateur: (*n*)	20 / 0 / 0	10 / 8 / 2	-	-
Handedness: (right / left / both) *(n)*	19 / 1 / 0	15 / 2 / 3	18 / 0 / 2	19 / 0 / 1
Affected hand: (right / left / both) *(n)*	-	14 / 4 / 2	-	16 / 2 / 2
Started playing at the age of: (*M* ± *SD*)[a]	8.6 ± 3.4	8.7 ± 3.1	39.2 ± 16.6	46.3 ± 11.7
Years of experience: (*M* ± *SD*)	31.2 ± 8.0	32.6 ± 8.6	12.0 ± 13.0	7.6 ± 5.2
Cumulative hs of experience: (*M* ± *SD*)	42095 ± 19294	29032 ± 16598	4036 ± 9114	2494 ± 2613
Onset age of symptoms: (*M* ± *SD*)	-	33.7 ± 8.2	-	50.3 ± 12.7
Years after onset: *(M* ± *SD)*	-	7.7 ± 6.2	-	3.6 ± 4.1
Years of experience until the onset (*M* ± *SD*)[b]	-	24.9 ± 7.6	-	4.3 ± 4.2

Abbreviations: M ± SD = mean ± standard deviation; HM = healthy musicians; DM = dystonic musicians; HG = healthy golfers; YG = yips-affected golfers. Instrument distribution for HM: piano 50%, violin 15%, violoncello 15%, flute 10%, clarinet 5% and horn 5%, (100% classical musicians) and for DM: piano 65%, guitar 20%, violin 5%, e-bass 5% and percussions 5%, (75% classical musicians, 20% jazz / rock / pop and 5% other). DM vs. YG: [a]$W = 210$, $z = -5.415$, $p < .001$, [b]$W = 190$, $z = -5.346$, $p < .001$.

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Table 1. Participant characteristics

Parameter	HM	DM	HG	YG
Age: years (*M* ± *SD*)	39.7 ± 8.5	41.3 ± 8.5	51.3 ± 14.1	53.9 ± 13.9
Gender: (female / male) (*n*)	3 / 17	3 / 17	2 / 18	2 / 18
Handicap: (*M* ± *SD*)	-	-	33.5 ± 18.7	27.4 ± 17.5
Occupation: Professional / semi-professional or music student / amateur: (*n*)	20 / 0 / 0	10 / 8 / 2	-	-
Handedness: (right / left / both) *(n)*	19 / 1 / 0	15 / 2 / 3	18 / 0 / 2	19 / 0 / 1
Affected hand: (right / left / both) *(n)*	-	14 / 4 / 2	-	16 / 2 / 2
Started playing at the age of: (*M* ± *SD*)[a]	8.6 ± 3.4	8.7 ± 3.1	39.2 ± 16.6	46.3 ± 11.7
Years of experience: (*M* ± *SD*)	31.2 ± 8.0	32.6 ± 8.6	12.0 ± 13.0	7.6 ± 5.2
Cumulative hs of experience: (*M* ± *SD*)	42095 ± 19294	29032 ± 16598	4036 ± 9114	2494 ± 2613
Onset age of symptoms: (*M* ± *SD*)	-	33.7 ± 8.2	-	50.3 ± 12.7
Years after onset: *(M* ± *SD)*	-	7.7 ± 6.2	-	3.6 ± 4.1
Years of experience until the onset (*M* ± *SD*)[b]	-	24.9 ± 7.6	-	4.3 ± 4.2

Abbreviations: M ± SD = mean ± standard deviation; HM = healthy musicians; DM = dystonic musicians; HG = healthy golfers; YG = yips-affected golfers. Instrument distribution for HM: piano 50%, violin 15%, violoncello 15%, flute 10%, clarinet 5% and horn 5%, (100% classical musicians) and for DM: piano 65%, guitar 20%, violin 5%, e-bass 5% and percussions 5%, (75% classical musicians, 20% jazz / rock / pop and 5% other). DM vs. YG: [a]$W = 210$, $z = -5.415$, $p < .001$, [b]$W = 190$, $z = -5.346$, $p < .001$.

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Table 3. Clusters (HPAS vs. NPAS) * Groups (Musicians vs. Golfers or HM vs. DM vs. HG vs. YG). Crosstabulations: 2x2 and 2x4

Clusters	**Cluster 1 (HPAS)** (n = 46) 57.5%				**Cluster 2 (NPAS)** (n = 34) 42.5%				*
Occupations (n)	**Musicians (29)**		**Golfers (17)**		**Musicians (11)**		**Golfers (23)**		
Occupations within clusters (%)	63.04		36.95		32.35		67.64		
Clusters within occupations (%)	72.50		42.50		27.50		57.50		
Groups (n)	**HM (15)**	**DM (14)**	**HG (8)**	**YG (9)**	**HM (5)**	**DM (6)**	**HG (12)**	**YG (11)**	
Groups within clusters (%)	32.60	30.43	17.39	19.56	14.70	17.64	35.29	32.35	
Clusters within groups (%)	75.00	70.00	40.00	45.00	25.00	30.00	60.00	55.00	

ns

Abbreviations: HM = healthy musicians; DM = dystonic musicians; HG = healthy golfers; YG = yips-affected golfers; HPAS = *High tendency to Perfectionism, Anxiety and - inability to cope with - Stress* profile; NPAS = *No tendency to Perfectionism, Anxiety and -inability to cope with Stress* profile; (*) = significant; *ns* = non-significant.

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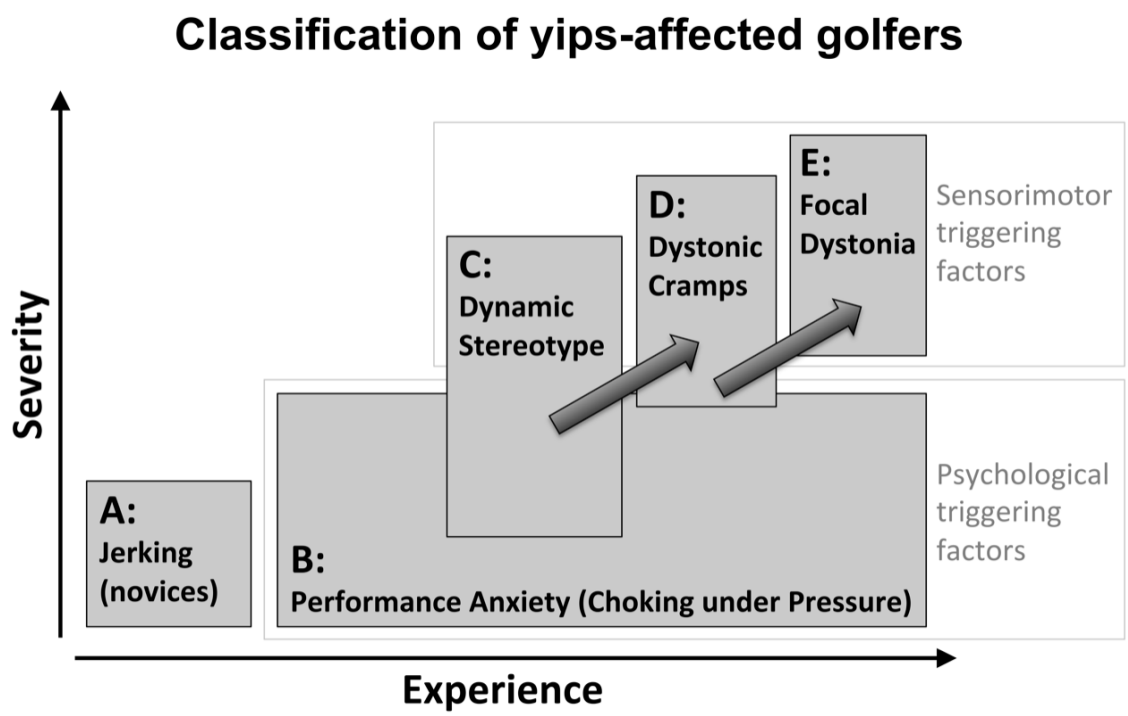
Classification of yips-affected golfers
Severity
A:
Jerking
(novices)
B:
Performance Anxiety (Choking under Pressure)
C:
Dynamic
Stereotype
D:
Dystonic
Cramps
E:
Focal
Dystonia
Sensorimotor
triggering
factors
Psychological
triggering
factors
Experience

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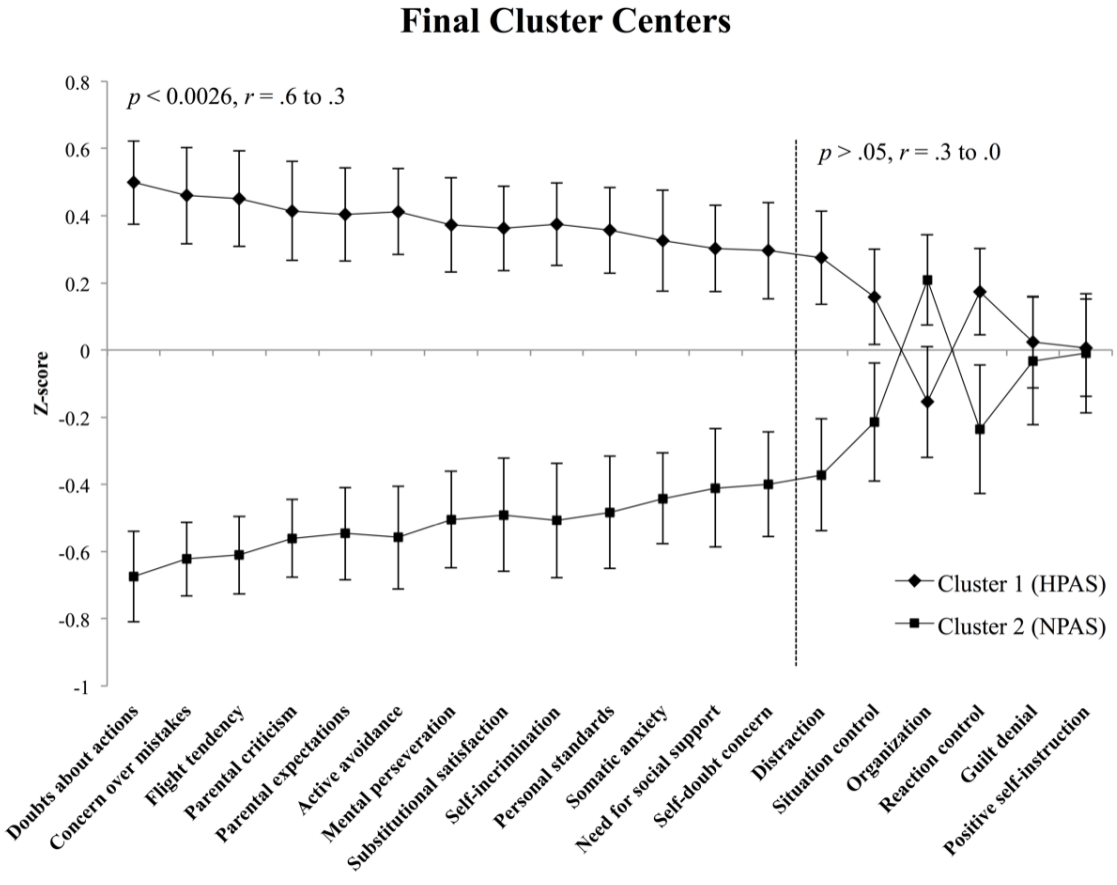
Final Cluster Centers
p < 0.0026, r = .6 to .3
p > .05, r = .3 to .0
Z-score
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Cluster 1 (HPAS)
Cluster 2 (NPAS)
Doubts about actions
Concern over mistakes
Flight tendency
Parental criticism
Parental expectations
Active avoidance
Mental perseveration
Substitutional satisfaction
Self-incrimination
Personal standards
Somatic anxiety
Need for social support
Self-doubt concern
Distraction
Situation control
Organization
Reaction control
Guilt denial
Positive self-instruction

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