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# The impact of stress on motor performance in skilled musicians suffering from focal dystonia: Physiological and psychological characteristics

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ABSTRACT

Recent investigations have suggested that stress can modulate motor function. However, the impact of stress on motor performance of musicians suffering from focal dystonia (FDM) remains unknown. The current study assessed motor performance in 20 FDM patients and 16 healthy musicians (HM) before and under stress. Stress was manipulated using the Trier Social Stress Test (TSST). Motor performance was evaluated based on analysis of electromyographic (EMG) activity and temporal variability, while electrocardiography (ECG) and the level of free cortisol were used to test for objective alterations of the hypothalamic-pituitary-adrenal (HPA) axis. Finally, the psychological profiles of both groups were analyzed using three psycho-diagnostic standardized questionnaires. Results showed that patients' motor impairments did not change under acute stressful conditions. However, an increase in muscular co-contractions was observed, reflecting a physiological muscular response under stressful conditions. Psycho-diagnostic analysis revealed higher levels of psychological traits related to elevated anxiety, stress and perfectionism in 40% of the patients. Although the motor outcome between those patients and those with an opposing psychological profile did not differ, patients characterized by stressful and perfectionistic personalities had, on average, developed dystonia about ten years earlier than the rest of the patients. The current study suggests that acute stress conditions may not have any direct impact on fine motor control of FDM patients. However psychological traits associated with increased stress, anxiety and perfectionism may have a long-lasting effect on the motor function of affected musicians, by promoting the acceleration or even the triggering of dystonia.



## 1. Introduction

Focal dystonia in musicians (FDM) is characterized by loss of motor control and by involuntary muscular contractions. It is a task-specific movement disorder, which affects the extensively trained fine-motor movements required to play a musical instrument. The professional performing careers of badly affected musicians can be terminated by dystonia (Altenmüller, 2003; Altenmüller and Jabusch, 2009, 2010). Numerous epidemiological studies have revealed that several intrinsic and extrinsic, genetic and psychological factors can contribute to the manifestation of dystonia (Altenmüller and Jabusch, 2010; Altenmüller et al., 2015; Conti et al., 2008; Frucht, 2009; Ioannou and Altenmüller, 2014; Schmidt et al., 2009; Schuele and Lederman, 2004). The pathophysiology of focal dystonia (FD) includes a lack of inhibition in sensory-motor systems, maladaptive neuronal dysfunctions such as distortion of sensory and motor receptive fields in the cortex and deficient sensory-motor integration (Breakefield et al., 2008; Elbert et al., 1998; Lin and Hallett, 2009; Torres-Russotto and Perlmutter, 2008). Further studies have revealed that alterations of the basal ganglia circuitry (Berardelli, 2006; Lin and Hallett, 2009; Tanabe et al., 2009) associated with dysfunctional pathways of the sensory thalamus (Lenz and Byl, 1999) and various cortical regions are also involved in the manifestation of FD (Delmaire et al., 2007; Egger et al., 2007; Garraux et al., 2004; Ibáñez et al., 1999; Pujol et al., 2000).

It has been suggested that movement disorders could share common neurobiological networks with several psychiatric diseases (Nikolova et al., 2011; Ron, 2009). With regard to FD, findings have suggested that neuropsychiatric or other psychological instabilities (e.g. fear, anxiety, stress etc.) form additional primary components of dystonia and are not simply psycho-reactive phenomena (Kuyper et al., 2011; Stamelou et al., 2012). Related pathophysiological findings have revealed that over-activity of the

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direct striatopallidal structures of the basal ganglia, which are associated with dystonia (Berardelli et al., 1998; Stefurak et al., 2003), are also involved in the mediation of cognitive and emotional processes (Alexander et al., 1990). Butler et al. (2007) used functional magnetic resonance imaging (fMRI) to investigate brain responses of healthy participants exposed to cognitively-induced fear. Interestingly, they found that brain structures (e.g. right caudate, bilateral anterior insula, bilateral thalamus etc.), which are traditionally associated with motor function, were highly active during the induction of conscious fear. Similar findings have been also reported by Phelps et al. (2001) and Lorberbaum et al. (2004). Butler et al. (2007) suggested that fear-induced processing involves motor control networks, including cortico-striato-thalamic loops. Further studies have suggested that the basal ganglia are involved in processing emotional information which is subsequently translated into behavioral responses (Grillner et al., 2005; Ring and Serra-Mestres, 2002). Dysfunctions of cortico-striato-thalamo-cortical loops have been associated with obsessive-compulsive disorder (OCD) symptoms (Harrison et al., 2009; Hou et al., 2014; Pauls et al., 2014; Posner et al., 2014). Further studies using transcranial magnetic stimulation (TMS) have demonstrated that exposure to psychological stress or negative emotions can also activate motor networks. Schutter et al. (2008), who stimulated healthy adults with TMS, revealed increases of the motor evoked potential in response to fearful facial expressions. Similar TMS studies have shown heightened corticospinal motor tract excitability to various emotional stimuli such as music and pictures, and pleasant or unpleasant images (Baumgartner et al., 2007; Hajcak et al., 2007). Other work has demonstrated that elevated levels of glucocorticoids induced by stress can promote maladaptive changes in the brain (Kim and Yoon, 1998; Krugers et al., 2006; Sapolsky, 1996; Tanapat et al., 1998). For example, studies have suggested that Parkinsonian symptoms get worse when associated with acute or chronic stress, probably due to the acceleration of neuronal death (Metz, 2007; Treves et al., 1990; Weiner and Lang, 1989). Finally, several investigations, based largely on subjective psycho-diagnostic assessments, have already demonstrated that a considerable proportion of patients suffering from FD have elevated levels of anxiety, somatization, stress, depression, or perfectionism, or suffer from obsessive-compulsive disorders and various phobias (Barahona-Corrêa et al., 2011; Bihari et al., 1992; Broocks et al., 1998; Cottraux et al., 1983; Enders et al., 2011; Gündel et al., 2001; Ioannou and Altenmüller, 2014; Lencer et al., 2009; Moraru et al., 2002; Mula et al., 2012; Müller et al., 2002; Munhoz et al., 2005; Nikolova et al., 2011).

A few studies have indicated that FDM in particular is associated with higher levels of anxiety, perfectionism, neuroticism and with social and/or specific phobias (Enders et al., 2011; Jabusch and Altenmüller, 2004; Jabusch et al. 2004b). In a recent investigation, psychological instabilities based on stress, anxiety and perfectionism were found in only half of the FDM patients, suggesting the existence of two sub-populations with different deficits in circuits of the cortico-basal ganglia-thalamic loops (Ioannou and Altenmüller, 2014). However, little is known about whether distinct psychological instabilities or different psychological profiles among FDM patients have any impact on motor processes. For example, previous electromyographic (EMG) studies underlined that muscle tone and muscular co-contractions are significantly increased in subjects with higher levels of anxiety and/or other emotional instabilities (Hazlett et al., 1994; Yoshie et al., 2008). Moreover, increased muscular activation and co-contraction was also observed in healthy subjects in response to psychological stress during execution of various motor activities (Ehrlenspiel et al., 2010; van Galen et al., 2002; Visser et al., 2004; Wahlström et al., 2003) or while playing a musical instrument (Yoshie et al., 2009). Finally Metz et al. (2005), who investigated modulations of rats' motor functions under stress, suggested that the motor system could be affected by stress either via hormonal or stress-associated emotional changes.

The aim of the current investigation was to address effects of stress exposure on the motor outcome of musicians suffering from FD. In order to examine this holistically we carried out three separate types of analysis. First, motor outcome differences between FDM patients and healthy musicians (HM) were examined. Second, participants were divided into those who responded (Stress-R) and those who did not respond (Stress-NR) to stress induction. This allowed performance differences between Stress-NRs and Stress-Rs to be identified before and after stress. Third, the psychological characteristics of all participants were examined and tested for possible impact on the motor performance of musicians. The induction of stress in laboratory conditions was achieved using the Trier Social Stress Test (TSST) (Ioannou et al., 2016; Kirschbaum et al., 1993). Alterations of the hypothalamic-pituitary-adrenal (HPA) axis were evaluated objectively by analyzing the level of free cortisol and electrocardiographic (ECG) activity. Additionally, stress arousal was subjectively self-evaluated using the state anxiety scale of the *State-Trait Anxiety Inventory* (s-STAI) (Spielberger et al., 1970). Motor output was evaluated through analysis of the temporal variability of finger movements and the muscular activity of the forearm during performance. The former used an established MIDI-Analysis-System (Jabusch et al., 2004a) and the latter was achieved by an electromyographic (EMG) analysis. Finally, the psychological profiles of all participants were evaluated via three standardized psycho-diagnostic questionnaires dealing with trait anxiety, stress coping strategies and perfectionism.

## 2. Methods

### 2.1. Participants

Twenty pianists with FDM affecting the right hand were randomly selected to participate from the database of the Institute of Music Physiology and Musicians' Medicine (IMMM) clinic. Sixteen healthy professional pianists formed a control group; they were either freelancers or recruited from music universities or orchestras. The two groups did not differ significantly in age ($U=147$, $z=-.414$, $p>.05$), gender ($p>.05$), handedness ($p>.05$) or professional situation ($p>.05$) (Fisher's exact, 2-sided). More details of participants' characteristics are provided in Table 1. The investigation was approved by the ethics committee of the Hanover Medical School and all participants gave their written informed consent prior to participation.

### 2.2. Apparatus and procedure

#### 2.2.1. Questionnaires

For the psychological evaluation all participants filled out three online psycho-diagnostic standardized questionnaires. The first was the *Competitive Trait Anxiety Inventory* (CTAI) (GER: Wettkampf-Angst-Inventar Trait (WAI-Trait), Brand et al., 2009), which is widely used in sport science. It assesses trait anxiety in competition (performance) situations. It consists of twelve items, scored on a 4-point scale (1="not at all" to 4="very much") and is divided into three subscales: (i) "somatic anxiety" (CTAIsa), (ii) "self-doubt concern" (CTAIsdc) and (iii) "concentration problems" (CTAIcp). The second questionnaire was the *Stress Coping Questionnaire* (SCQ) (GER: Stressverarbeitungs-Fragebogen (SVF-78), Erdmann and Janke, 2008), which assesses different ways of coping with stress. The SCQ consists of 78 items, each evaluated on a scale ranging from 0="not at all" to 4="most likely". It is mainly divided into positive stress coping behaviors (stress reduction; SCQ-POS) and negative stress coping behaviors (stress increase; SCQ-NEG). Finally the German version of the *Frost Multidimensional Perfectionism Scale* (FMPS) (Frost et al., 1990) (GER: Mehrdimensionale Perfektionismus Skala von Frost (MPS-F), Altstötter-Gleich and Bergemann, 2006) was used to examine different features of perfectionism. It consists of 35 statements, scored on a 6-point scale ranging from 1="does not apply at all" to 6="applies very well" and is divided into six subscales: "concern over mistakes" (CM), "personal standards" (PS), "parental expectations" (PE), "parental criticism" (PC), "doubts about actions" (DA) and "organization" (O). For further details concerning the use of all these instruments, see Ioannou and Altenmüller (2014). In order to subjectively assess participants' state anxiety during