A VECTOR CODING PERSPECTIVE ON BREATHING COORDINATION: TWO CYCLISTS' HANDLEBAR POSITIONS ANALYSIS

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This study introduces a novel approach by applying the vector coding technique to describe the coordination of thoracoabdominal respiratory movements of two hand support positions adopted by cyclists during pedaling. Eleven male cyclists alternated between high and low hand positions. Breathing kinematic analysis during cycling using a 3D motion capture system provided compartmental volumes (superior and inferior thorax, and abdomen) of the breathing cycles. Predominant in-phase coordination among compartmental pairs was found, however, in a few cases, the transition phase from inspiration to expiration may induce an anti-phase pattern. This was mainly seen in Superior Thorax vs. Inferior Thorax, with 19.1% [10.1 – 26.7] during high hands and 27.2% [12.8-32.5] in the low hands position. The influence of hand positions on coordination was minimal, except for one subject.

KEYWORDS: Respiratory Mechanics, Coordination, Cyclists

INTRODUCTION: The coordination pattern during breathing is typically assessed using the phase angle method, which discretizes the respiratory curve, condensing information from the respiratory movement cycle consisting of inspiratory and expiratory phases, each influenced by different muscle groups. Recently, a dynamical systems approach has been applied to explore coordination patterns across various breathing frequencies at rest, emphasizing the significance of incorporating this approach into respiratory pattern assessment (Higashino, 2022). In the complex domain of sporting activities, the expansion of respiratory compartments can be influenced by various factors. For example, the positioning of cycling handlebars, as explored by Charlton (2017), has been shown to impact the ventilatory work of breathing. This influence is achieved through increased trunk flexion and shoulder abduction, potentially altering the dynamics of compartmental contribution. Such alterations may restrict superior thoracic cage excursion, consequently shifting the respiratory pattern towards the inferior thorax (Lopes, 2023). Investigating potential alterations in the coordination pattern throughout the entire breathing cycle during sports tasks, particularly considering the influence of hand positions, could offer valuable insights into the nuanced relationship of thoracoabdominal movement patterns. Thus, this study aims to describe the coordination of thoracoabdominal respiratory movements using a vector coding technique in two hand support positions adopted by cyclists during pedaling.

METHODS: Participants had to fulfill the following conditions: 1) be between 20 and 30 years old, 2) have a minimum of 5 years of competition experience at the national level, 3) have covered an average distance of 25,000 km (training and competition) in the preceding season, 4) be non-smokers, and 5) exhibit good overall health with the absence of lung-related conditions. Eleven male cyclists (age: 24±3.8 years, weight: 61.9±8.5 kg, height: 1.7±0.1 m, VO2max: 65.31±6.12 L/min), all members of a licensed professional team, were enrolled. Participants were instructed to avoid intense training the day before the single-day lab experiment. The study received approval from the Institutional Review Board in adherence to the Declaration of Helsinki, and all participants provided written informed consent. The cyclists underwent a cycling task composed by 12 minutes of exercise at 100 watts on a cycle ergometer (Lode Excalibur Sport, Groningen, Netherlands), adjusted according to each

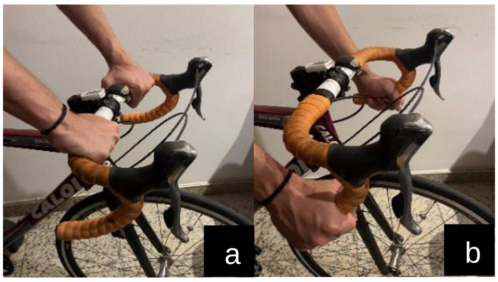

Figure 1: Hand position on the handlebar: a - high, b - low

cyclist's bike positioning. They were instructed to alternate between high (hands on the straight part of the handlebars) and low (hands on the curved part of the handlebars) positions randomly (Figure 1). The protocol involved acquiring thoracoabdominal kinematics using the 12 Optitrack cameras (Prime 17W, 100Hz) by the optoelectronic system (Natural Point, USA). Thirty-two retro-reflective markers (Ferrigno, 1994) placed on the trunk enable the division into three compartments: superior thorax (ST), inferior thorax (IT), and abdomen (AB). The 3D coordinates of these markers were reconstructed and smoothed using a Butterworth filter with a cutoff frequency of 10Hz. The prism-based method was then employed to calculate the compartmental volumes from the smoothed coordinates. One minute of each hand position were recorded and the volume of each compartment, represented over time, was segmented into breathing cycles (minimum to minimum) and normalized to 100% of the cycle duration for each hand position. The coordination was calculated using the vector coding technique (Chang, 2008) for each instant of the mean normalised breathing cycle. The coupling angle between two compartments was acquired and subsequently utilized to calculate the group phase, represented by the percentage distribution across four coordination patterns: first compartment x second compartment: 1. in-phase with first compartiment dominance, 2. in-phase with second compartiment dominance, 3. anti-phase with first compartiment dominance and 4. anti-phase with second compartiment dominance (Needham, 2020). The respective classification was applied to the STxAB, ITxAB compartimental pairs. In-phase coordination denotes simultaneous volume increases in two compartments, whereas anti-phase coordination indicates that while one compartment's volume increases, the other's decreases. Compartmental dominance refers to a more pronounced change in the volume range of one compartment over the other at each instant in time during a movement cycle. The group phase, quantified by the percentage distribution across four coordination patterns, was employed to delineate the coordination dynamics among compartment pairs (STxIT, STxAB, ITxAB) relative to hand positions (high and low) throughout the respiratory cycle.

RESULTS: The percentage of the four coordination patterns for each subject are shown in STxIT (Figure 2), STxAB (Figure 3) and ITxAB (Figure 4).

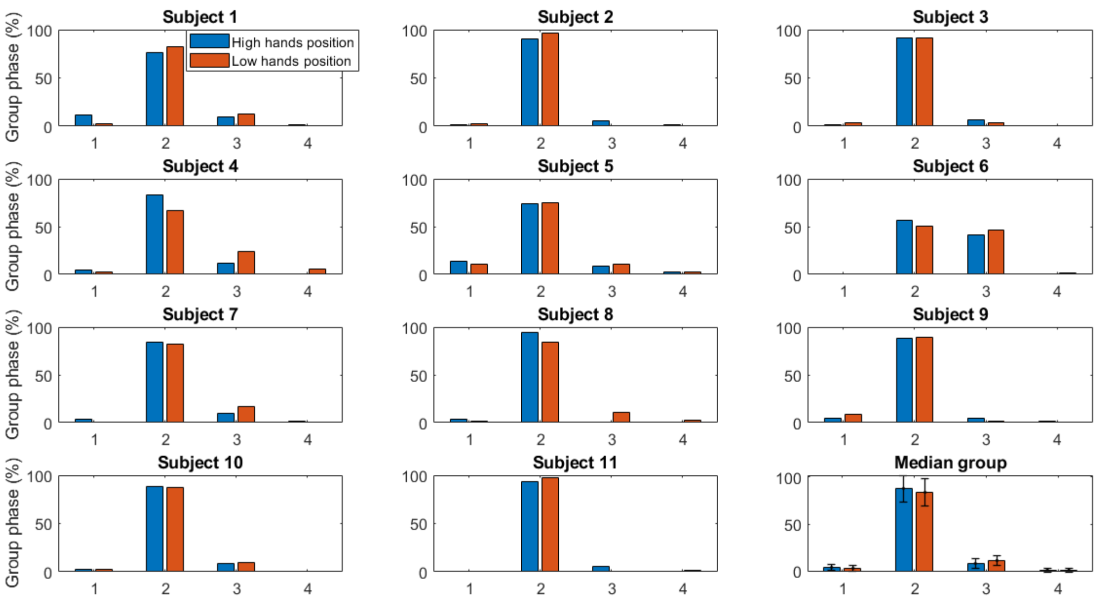

Figure 2: Group phase of STxIT during the breathing cycle between high and low hands positions. 1. In-phase ST dominance, 2. In-phase IT dominance, 3. Anti-phase ST dominance, 4.

Anti-phase IT dominance. The subplots represent distinct subjects, and the last subplot depicts the median and interquartile interval for the entire dataset.

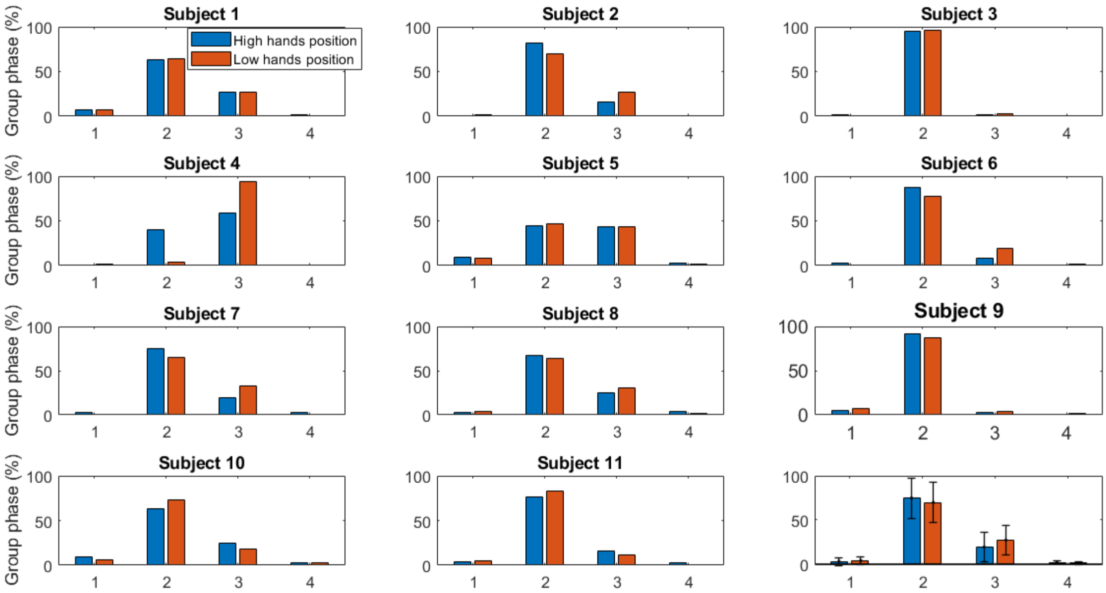

Figure 3: Group phase of STxAB during the breathing cycle between high and low hands positions. 1. In-phase ST dominance, 2. In-phase AB dominance, 3. Anti-phase ST dominance, 4. Anti-phase AB dominance. The subplots represent distinct subjects, and the last subplot depicts the median and interquartile interval for the entire dataset.

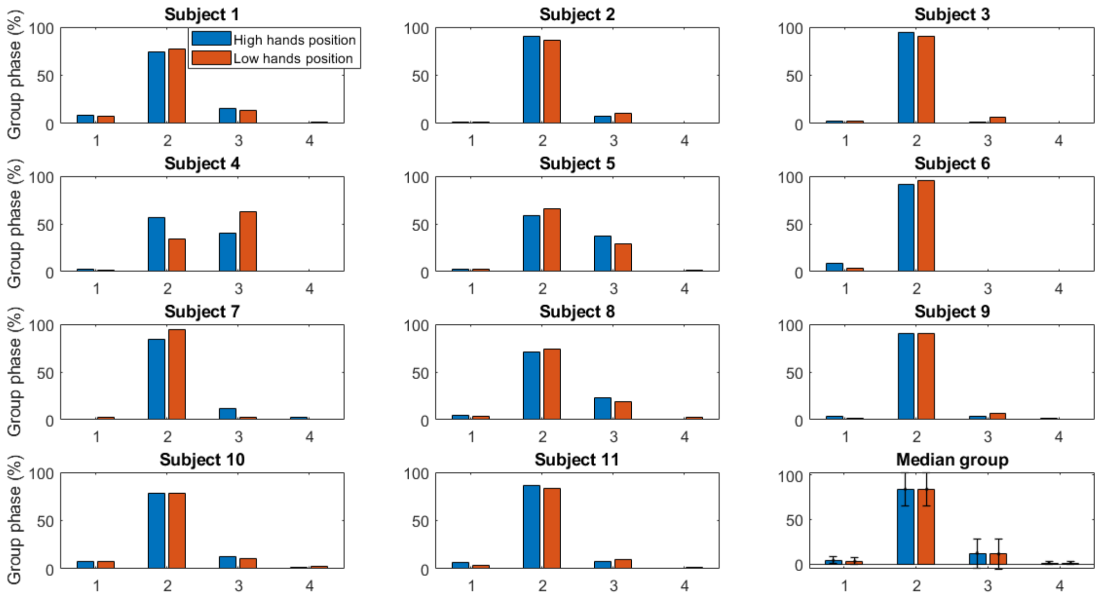

Figure 4: Group phase of ITxAB during the breathing cycle between high and low hands positions. 1. In-phase IT dominance, 2. In-phase AB dominance, 3. Anti-phase IT dominance, 4. Anti-phase AB dominance. The subplots represent distinct subjects, and the last subplot depicts the median and interquartile interval for the entire dataset.

DISCUSSION: Primarily, this study offers a comprehensive overview of the coordination patterns exhibited by each cyclist, intending to highlight the similarities and differences observed during the breathing cycle. In examining the coordination between the Superior Thorax (ST) and Inferior Thorax (IT), all cyclists consistently demonstrated an in-phase coordination pattern, emphasizing the dominance of IT compartmental volume over ST during cycling tasks, in line with findings from a previous study (Lopes, 2023). A noteworthy exception was observed in one cyclist (subject 6) who, in addition to the mentioned pattern, exhibited an

anti-phase coordination with ST compartmental volume dominance. This pattern was manifested during the transition between breathing phases, signifying that as the superior thorax expanded to inspire, the inferior thorax concurrently decreased to expire.
Turning to the coordination between ST and Abdomen (AB), two distinct patterns emerged. The majority of cyclists displayed an in-phase coordination with AB compartmental volume dominance, also aligning with the findings of Lopes et al. (2023) that shown a major contribution of the abdominal compartment to breathing during cycling tasks. However, a contrasting pattern was identified, indicating either a dominant (one subject) or secondary anti-phase ST compartmental volume dominance. The median and interquartile range for anti-phase coordination within these pairs of compartments (STxAB) exhibited higher values in comparison to others. Specifically, the median was 19.1%, and the interquartile range was [10.1 – 26.7] during the high hands position. Notably, these values increased during the low hands position, reaching 27.2% [12.8-32.5]. This suggested that, as the superior thorax continued to expand, the abdomen decreased during the expiration phase.
Finally, IT and AB coordination revealed a consistent in-phase pattern with AB compartmental volume dominance. Additionally, a potential shift to an anti-phase pattern during the transition from inspiration to expiration was noted, with anti-phase IT dominance.
In most cases, the hand position on the handlebar does not seem to exert a significant influence on the coordination between compartments. However, an exception was observed between the STxAB compartments mainly with subject 4, where the low hand position appeared to have a detrimental effect on the coordination, resulting in a notable anti-phase pattern with ST dominance. Further analysis could delve into the factors contributing to this adverse pattern. To our knowledge, this study is the first to apply the vector coding technique for respiratory analysis, limiting our potential for direct comparison with existing literature. Nevertheless, we aim to initiate a discussion for further insightful analyses.

CONCLUSION: In conclusion, the coordination observed among the three compartmental pairs during the cycling task predominantly demonstrates an in-phase pattern. Nonetheless, in some cases, the transition phase from inspiration to expiration may induce an anti-phase pattern, as one compartment continues to inspire while the other begins to expire, mainly in STxAB pair compartments. Further analyses examining the potential consequences of this behaviour, particularly during higher intensities that result in increased breathing frequency and, consequently, an elevated velocity of shortening of breathing muscles, could offer valuable insights into the coordination patterns of breathing during exercise.

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