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ACUTE METABOLIC RESPONSE AND HYDRATION STATUS DURING EXERCISE UNDER HYPOXIC CONDITION IN MALE COLLEGIATE FOOTBALL PLAYERS

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ABSTRACT

Background: Simulated hypoxia has popularly been used to determine the short-term physiological responses to hypoxic condition. This study aimed to investigate the effect of acute hypoxic exposure on metabolic responses and hydration status during exercise in collegiate football players. **Method:** Six male collegiate football players voluntarily participated in this study. A randomized cross-over design was employed. Participants were asked to complete two exercise trials under Normoxic (NC: FIO_2 21%) and Hypoxic (HC: FIO_2 15%) conditions. The exercise trial was conducted on a cycle ergometer at a constant workload corresponding to 70% of $\dot{V}O_{2peak}$ for 60 min, followed by a 15-min recovery period. Metabolic variables, including oxygen consumption ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$) and respiratory exchange ratio (RER) were measured at rest, during exercise at 20, 40, 60 min, and every 5-min intervals during the recovery period. Hydration status was analyzed before and after exercise. **Result:** All resting data were not different between two conditions. Whilst $\dot{V}O_2$ and $\dot{V}CO_2$ increased throughout the exercise period in both conditions ($p<0.05$), no significant difference was observed between NC and HC ($p>0.05$). Average RER were 0.88 and 0.91 at rest in NC and HC, respectively. RER were significantly increased from resting values ($p<0.05$), but there was no significant difference between conditions. During the recovery period, $\dot{V}O_2$ and $\dot{V}CO_2$ remained higher than the resting values in both conditions, suggesting that metabolic profiles were not fully recovered within 15 min. Urine specific gravity after exercise under HC was significantly higher than in NC. ($p<0.05$). Percent change of urine specific gravity under NC and HC were 0.5% and 1.2%, respectively. **Conclusion:** Metabolic responses during exercise under the acute hypoxic exposure did not differ from the normoxic condition. Therefore, the hypoxic condition (FIO_2 15%) does not show significant negative effects during submaximal exercise in collegiate football players.

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Keywords: Hypoxic/ Exercise / Metabolic function / Constant load / Dehydration

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การเปลี่ยนแปลงการตอบสนองทางเมตาบอลิคและสภาวะน้ำในร่างกายระหว่างการออกกำลังกายภายใต้สภาวะออกซิเจนเบาบางเฉียบพลัน

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บทคัดย่อ

การจำลองสภาวะออกซิเจนเบาบาง นำมาใช้ประโยชน์ในการฝึกซ้อมในสภาวะออกซิเจนเบาบาง และยังได้รับความนิยมนำมาใช้ฝึกร่างกายเพื่อให้เกิดการเปลี่ยนแปลงทางสรีรวิทยา การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาผลระหว่างการออกกำลังกายในสภาวะออกซิเจนเบาบางเฉียบพลันกับการเปลี่ยนแปลงของระบบเมตาบอลิคและสภาวะน้ำในร่างกายในนักกีฬาฟุตบอลมหาวิทยาลัย โดยคัดเลือกอาสาสมัครผู้เข้าร่วมวิจัยเป็นนักฟุตบอลมหาวิทยาลัยเพศชาย จำนวน 6 คน เพื่อเข้าร่วมการศึกษาทั้งหมด 2 ครั้ง แบ่งออกดังนี้ การออกกำลังกายแบบทนทานที่ความหนักคงที่ ที่ระดับ 70% ของอัตราการใช้ออกซิเจนสูงสุดทั้งในสภาวะออกซิเจนปกติและออกซิเจนเบางบางเฉียบพลัน โดยแต่ละครั้งจะประกอบด้วย ช่วงการออกกำลังกาย 60 นาที และช่วงพักฟื้นร่างกาย 15 นาที ตัวแปรที่ถูกวัดระหว่างออกกำลังกายได้แก่ ความสามารถในการใช้ออกซิเจน อัตราการเกิดคาร์บอนไดออกไซด์ และอัตราส่วนการแลกเปลี่ยนการหายใจ จะทำการวัดในขณะพัก ระหว่างการออกกำลังกายนาทีที่ 20, 40, 60 และในระยะฟื้นตัวทุกๆ 5 นาที สภาวะน้ำในร่างกายจะทำการวัดก่อน-หลังการออกกำลังกาย ผลการศึกษาพบว่า ในขณะพักก่อนออกกำลังกายไม่พบความแตกต่างกันในทุกตัวแปรทั้งในสภาวะออกซิเจนปกติและออกซิเจนเบาบางเฉียบพลัน ($p>0.05$) ในขณะที่อัตราการใช้ออกซิเจน อัตราการเกิดคาร์บอนไดออกไซด์สูงขึ้นอย่างมีนัยสำคัญตลอดระยะเวลาการออกกำลังกาย ($p<0.05$) แต่ไม่พบความแตกต่างระหว่างสภาวะออกซิเจนปกติและสภาวะออกซิเจนเบาบาง ค่าเฉลี่ยอัตราส่วนการแลกเปลี่ยนการหายใจในขณะพักอยู่ที่ 0.88 และ 0.91 ในสภาวะออกซิเจนปกติและสภาวะออกซิเจนเบาบางตามลำดับ ค่าอัตราส่วนการแลกเปลี่ยนการหายใจในขณะออกกำลังกายเพิ่มขึ้นอย่างมีนัยสำคัญจากช่วงขณะพัก แต่ไม่มีความแตกต่างระหว่างสองสภาวะในช่วงการฟื้นตัวพบว่าอัตราการใช้ออกซิเจน อัตราการเกิดคาร์บอนไดออกไซด์ยังคงค่าสูงกว่าในขณะพักทั้งในสองสภาวะ ซึ่งเป็นสิ่งแสดงให้เห็นว่า ระยะพักฟื้น 15 นาที ไม่เพียงพอต่อการฟื้นฟูอย่างเต็มประสิทธิภาพ ค่าความถ่วงจำเพาะปัสสาวะหลังการออกกำลังกายพบว่าในสภาวะออกซิเจนเบาบางเฉียบพลันมีค่าสูงกว่าในสภาวะออกซิเจนปกติอย่างมีนัยสำคัญ ($p<0.05$) สรุปผลการศึกษา การศึกษานี้ไม่พบความแตกต่างทางสถิติของตัวแปรทางเมตาบอลิคทั้งในสภาวะออกซิเจนปกติและสภาวะออกซิเจนเบาบาง ซึ่งทำให้สรุปได้ว่าไม่มีความแตกต่างของการเปลี่ยนแปลงทางสรีรวิทยาระหว่างการออกกำลังกายภายใต้สภาวะออกซิเจนเบาบางเฉียบพลันและสภาวะออกซิเจนปกติ ดังนั้นสภาวะออกซิเจนเบาบางเฉียบพลันในระดับ FIO_2 15% ยังไม่ต่ำพอที่จะมีผลกระทบเชิงลบต่อประสิทธิภาพการออกกำลังกายในนักฟุตบอลระดับมหาวิทยาลัย

วารสารวิทยาศาสตร์และเทคโนโลยีการกีฬา 2561 ; 18(1): 27-36

คำสำคัญ: สภาวะออกซิเจนเบาบาง / ออกกำลังกายที่ความหนักคงที่ / กระบวนการเผาผลาญ / สภาวะร่างกายขาดน้ำ

INTRODUCTION

The response of physiology function to hypoxia is known to change when traveling above 2000 meters from sea level.[1] The real altitude environment constitutes of hypoxic/hypobaric and low temperature, which causes general symptoms such as shortness of breath, wheezing and dizzy.[2] This can develop to hyperventilatory compensation, water loss and dehydration.[3] Exercise in acute normobaric hypoxia has been shown to cause a rise in sympathetic activity, a decline in oxygen delivery, increased in peripheral vasoconstriction and a rise in heat storage.[4, 5] Simulating hypoxia has been used to investigate the acute physiological responses to low oxygen level. Hypoxic chamber has been used to simulate low oxygen conditions by decreasing percentage of inspired oxygen concentration (hypoxic condition) where the atmospheric pressure, at sea level, is kept constant at 760 mmHg (normobaric condition).

Nevertheless, most studies focused on cardiorespiratory function[6-9] or physiological function and exercise performance in hypoxic condition[2, 10-13], but a few studies reported on the metabolic responses to exercise in the simulated acute hypoxic condition. Many studies showed a decrease in maximal oxygen consumption ($\dot{V}O_{2max}$) in acute hypoxic condition.[1] In contrast, some evidences showed that $\dot{V}O_{2max}$ unchanged during exercise in acute hypoxia exposure.[14] In addition, previous research has not clearly shown the physiological responses to exercise in the simulated hypoxic condition. The metabolic change during acute hypoxic exposure is possibly the results of 2% dehydration or defined that acute hypoxia caused greater dehydration, a decline in oxygen delivery and reduction in aerobic capacity, which may induces metabolic deteriorations.[10, 11] Therefore, the acclimation during exercise in acute hypoxia is important to maintain metabolic, physiological and functional performance.

Acute hypoxic and dehydration cause hypovolemia, vasoconstriction, compensatory rise in heart rate, and a decline in oxygen delivery and heat dissipation were reported.[4, 5] Therefore, we hypothesized that in acute hypoxia compared with normoxic: acute hypoxia would impair metabolic function and individual's hydration status would show a dehydration response to acute hypoxia as shown by ventilatory responses. Thus, the aims of this study was to investigate the effects of acute hypoxic exposure on metabolic response during exercise and hydration status after exercise in collegiate football players.

MATERIALS AND METHODS

Participants

Six male collegiate football players, aged between 18-22 years, voluntarily participated in this study, after giving written informed consent form. They were regularly involved in exercise for 3-5 days/week. Participants were nonsmokers and had no experience on either living or spending time on 2,000 meters above sea level. Participants had no history of cardiovascular and/or respiratory disease and lower limb injury before participating in this study. All procedures were approved by the local Ethics Committee on Human Experimentation of Mahidol University Institutional Review Board (MU-IRB 2014/027.1302).

Experimental Design

A randomized cross-over design was employed. All participants were required to attend the laboratory on 3 visits, with at least 5 days apart for washout period.[7] Participants were completed two conditions including Normoxic (NC) and Hypoxic (HC) conditions. First, they were collected anthropometric data and the peak rate of oxygen consumption ($\dot{V}O_{2peak}$) assessment by gas analyzer (Oxycon® mobile, Germany). The next 2 visits involved a cycling at 70% of $\dot{V}O_{2peak}$ for 60 min in NC (FIO_2 21%) and HC (FIO_2 15%) conditions, using a hypoxic chamber (Altitude Technology Solutions Pty Ltd., ATS Global).[15, 16] Room temperature was controlled at 25-26°C throughout the experiment. After exercise period, participants were asked to complete 15-mins recovery period by cycling at zero workload. All outcome variables were continuously monitored throughout the experiment. Body composition and urine specific gravity measured using body fat analyzer (OMRON® HBF-362, Japan) and urine refractometer (ATAGO®, Japan), respectively, at baseline and immediately after exercise.

Graded Exercise Test

The graded exercise test protocol was used to determine the $\dot{V}O_{2peak}$ using a Monark cycle ergometer (Monark® 828E, Sweden). The testing protocol was consisted of a 5-mins warm-up, followed by cycling at 80 watts with 60 rpm for 3 min, then the work rate was increased by 40 watts every 3 mins until voluntary exhaustion. All participant were encouraged to give their maximum effort. The criteria to achieve the maximum of $\dot{V}O_2$ were 1) the level of $\dot{V}O_2$ increased less than 2 $ml \cdot kg^{-1} \cdot min^{-1}$ after 2 mins, 2) heart rate exceeds its predicted maximum, and 3) the respiratory exchange ratio exceeds 1.2.[17]

The constant-load exercise test

The constant-load exercise involved 80 mins exercise duration. The exercise protocol included a 5 mins warm-up, followed by 60 mins exercise and a final 15 min recovery period. Exercise involved participants cycling on cycle ergometer at 70% of $\dot{V}O_{2peak}$ while at a pedaling rate of 55-60 rpm and non-workload during recovery period.[18] Metabolic variables were collected using gas analyzer mobile, which is the mobile unit used for investigations of both rest and/or exercise condition. All variables were recorded breath by breath pattern cover all over of experiment. Urine specific gravity was measured hydration status. Urine osmolality was assessed using a normal range of 1.000 to 1.030.[19]

Statistical Analysis

All data were averaged over 20 mins, 5 mins intervals during exercise and recovery period, respectively. Data were presented as mean and standard error of mean. The normal distribution and sphericity of the data was determined using a *Kolmogorov's Smirnov test* (K-S test). An unpaired *t*-test was used to analyze group mean differences (NC and HC) for percent weight loss and percent change of urine specific gravity. Data differences between trails over time were analyze using a repeated measures analysis of variance (ANOVA). All data were analyzed using a SPSS (version 23.0) software, with the significant level set at $p<0.05$.

RESULTS

All participants completed NC and HC conditions. Their characteristics were shown in Table 1. The mean of %weight loss and urine specific gravity after exercise in NC and HC condition were presented in Table 2. Although there was a trend for %weight loss to increase with NC conditions ($p>0.05$), no significant difference was observed between conditions. Exercise under NC and HC conditions induced weight loss of 1.4% and 1.2% of body weight, respectively. The urine specific gravity, presented as percent from initial value, after exercise under HC conditions were significantly higher than NC conditions. ($p<0.05$).Percent change of urine specific gravity under NC and HC were 0.5% and 1.2%, respectively.

Table 1. General characteristics of participants.

Physical characteristics	Mean±SD
Age (yrs)	19.8±1.2
Height (cm)	175.5±6.3
Weight (kg)	71.5±6.3
%Body fat	17.1±3.7
Lean body mass (kg)	35.5±1.5
$\dot{V}O_{2max}$ ($ml{\cdot}kg^{-1}{\cdot}min^{-1}$)	35.5±5.4

Table 2. Body weight loss and Urine specific gravity of participants between normoxic and hypoxic conditions.

	Normoxic		**Δ**%	Hypoxic		**Δ**%
	Pre	Post		Pre	Post	
Weight loss	70.4±2.4	69.4±2.4	-1.4%	71.0±2.8	70.2±2.8	-1.2%
Urine specific gravity	1.020	1.025	0.5%	1.013	1.025	1.2%*

*Significant difference between NC and HC ($p<0.05$)

The metabolic variables at resting, during exercise and recovery period between normoxic and hypoxic conditions as shown in Figure 1. Data revealed that the metabolic variables during exercise in NC and HC conditions were slightly higher than the resting values.[19] However, no significant difference among the conditions were found. In addition, there was a similar pattern of significantly decline of metabolic variables among conditions during the recovery.

Heart rate (HR) at rest, during exercise and recovery period was similar between two conditions. In addition, HR during recovery remained significantly higher than that of initial values ($p<0.05$), indicating that there was no complete recovery in cardiac rhythms. NC had no significant effect on oxygen saturation (SpO_2) during exercise. However, HC significant lower SpO_2 since beginning of exercise (Figure 2(a)). During recovery period, SpO_2 had returned nearly to a resting value, for both conditions.

Figure 1. $\dot{V}O_2$ (a), $\dot{V}CO_2$ (b), RER (c) and Respiratory Rate (d) at rest, during exercise and recovery period between normoxic (NC) and hypoxic (HC) conditions.

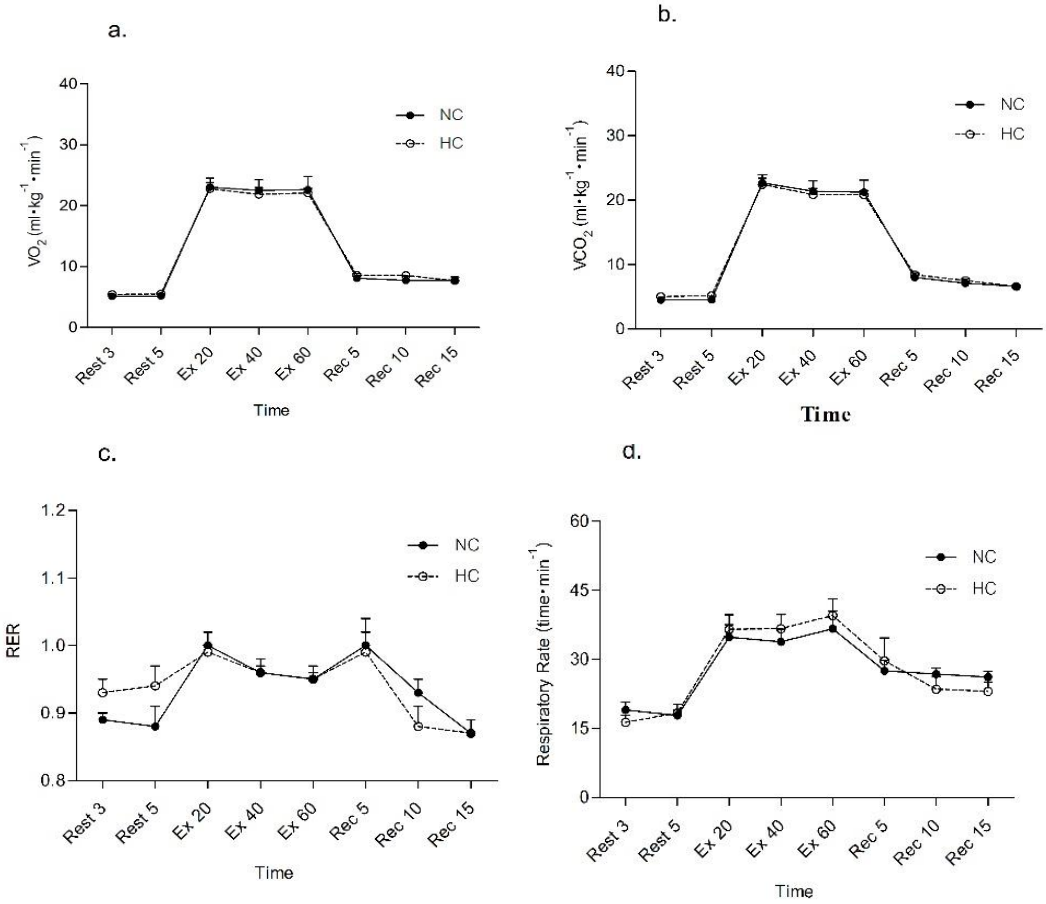
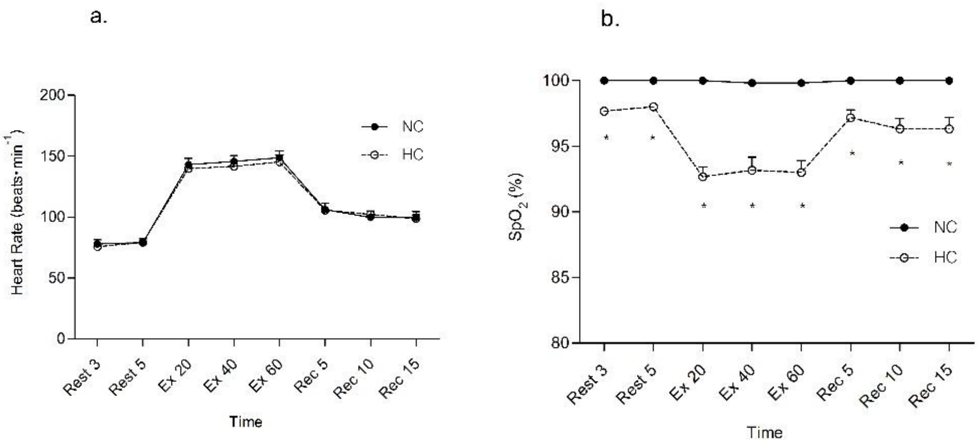


Figure 2. Heart rate (a) and SpO_2 (b) at rest, during exercise and recovery period between normoxic (NC) and hypoxic (HC) conditions.



*Significant difference between NC and HC (*p*<0.05)

DISCUSSION

This study aimed to investigate the effect of acute hypoxic exposure on metabolic function and hydration status in collegiate football players. The major finding of the study was an acute hypoxic exposure did not impair metabolic function of collegiate football players. However, analysis of hydration status showed low levels of dehydration 1.4% and 1.2% in both NC and HC conditions, respectively.

Theoretically, water intake at the same amount of water loss contributes will reduce thermal accumulation, maintain body function and reduce exercise stress in human body.[20] It was reported that fluid loss may affect to impair physical performance.[21] Dehydration can cause headache, difficulty in breathing, chest or abdominal pain, hypovolemia, vasoconstriction, compensatory rise in heart rate, decline oxygen delivery and heat dissipation. Dehydration more than 2% of body weight loss can reduce endurance performance and further dehydration can effect on health and cognitive function.[10] The performance can decrease capacity about 30% by losing water 5% of body weight.[21] The combination of hypoxic and dehydration effects to physical stress and lead to reduced performance independently.[11] Mechanisms for explaining this is increased cardiovascular and thermoregulatory strain. Previous studies, exercise at 70% of $\dot{V}O_{2max}$ for 60 mins induces 1.8% of body weight loss. The present study found that moderate exercise at 70% of $\dot{V}O_{2peak}$ in NC and HC conditions, causes reduce in body weight of 1.44% and 1.18%, respectively. In this study indicated that the level of water loss is only low level of dehydration. In previous, very few studies has been focused on water loss during exercise under hypoxic condition.[22, 23] They mostly concerned on water loss under hypoxic condition without exercise interventions.[24] The present study is, therefore, unique to present the combination of exercise and hypoxic condition.

The metabolic values in all conditions of this study showed higher than normal range, which may be the result from unusual breathing via face mask. The metabolic changes is a result of exercise, which lead to higher demand for more energy utilized.[25] Levels of metabolism during recovery were higher than resting values as the factor of excess post-exercise oxygen consumption (EPOC).[26] The present study, when the exercise was terminated, biochemical process remains in activation stage and lasted more than 15 mins. Therefore, this study recommends those who exercise either hypoxic or normoxic condition at/or above moderate intensity to let recovery more than 15 min after exercise. The present study showed that $\dot{V}O_2$ values during exercise in all conditions are not significantly different throughout the experiment. This is consistent with Schmitt et al. (2002) studied in animal model, which reported no significant differences between conditions, however, they found that there was a significant difference of $\dot{V}O_2$ between exercise and rest period. It was similar in the present study.[26] Respiratory exchange ratio remained higher than resting period, when exercise was terminated. But RER in both condition are not significantly different throughout the experiment. An increase in RER in this study may be the result of the continuity of biochemical process after exercise. Post-exercise oxygen consumption (EPOC) mechanism can be explain that level of metabolism during recovery period were higher than resting period, its one factor of this process.[27] Another factors such as physical activity, food intake, emotional and time of the day, it was also affect metabolic function. However, intensity, duration and type of exercise provide a different post-exercise metabolic function.[28]

Heart rate in this study was not significantly different between conditions. Also supported by Peltonen et al. (2001) found cardiac function was no different during exercise between normoxic and hypoxic.[29] Under hypoxic conditions found that SpO_2 decreased as a result of low oxygen in inspired air, which later caused low gradient of O_2.[30] The present study found that SpO_2 was significantly lower in HC than NC conditions throughout the experiment. The result was the same as Friedmann et al. (2004), where SpO_2 was decreased in hypoxia and unchanged during the endurance exercise in normoxic.[25] Normally, the acceptable minimum SpO_2 in human with normal conscious is about 90%, if less than 90% will begin with blur and dizzy. However, all of the symptom will be back to normal sign, when the body functions can acclimation or return to sea level.

CONCLUSION

In conclusion, an acute hypoxic exposure (FIO_2 15%) had no significant effects on metabolic function during exercise, except for water loss, when compare to normoxic condition. Thus, we suggest that water drinking is required for its positive effects as we exercise under hypoxic conditions.

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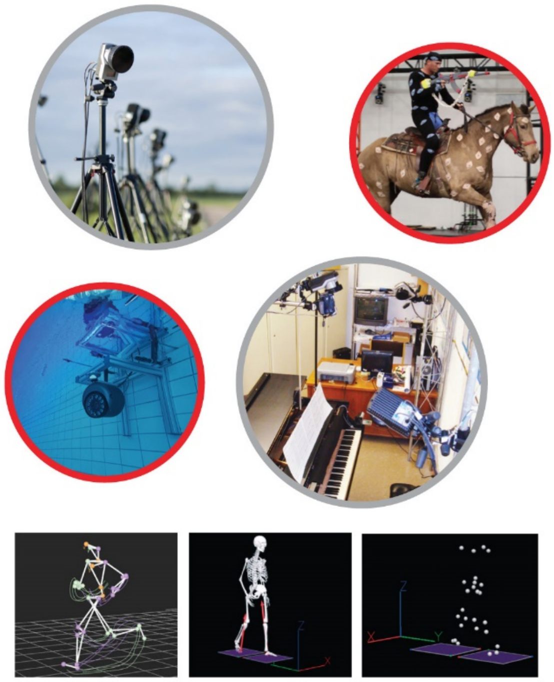

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