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Respons Fisiologis, Performa Kognitif, dan Oksigenasi pada Prefrontal Cortex Akibat Paparan Suhu Dingin di Cold Storage
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INTISARI

Pekerja *cold storage* di wilayah beriklim tropis berisiko mengalami gangguan fisiologis dan kognitif akibat paparan suhu dingin ekstrem. Individu yang tumbuh dan beradaptasi di lingkungan tropis lebih rentan terhadap *cold stress* dibandingkan populasi di iklim dingin, mengingat perbedaan karakteristik termoregulasi mereka. Namun, kajian yang secara terintegrasi mengkaji respons fisiologis, performa kognitif, dan oksigenasi *prefrontal cortex* (PFC) pada konteks *cold storage* masih terbatas. Penelitian ini bertujuan menganalisis pengaruh paparan suhu dingin ekstrem terhadap respons fisiologis, performa kognitif, dan oksigenasi PFC, serta mengkaji perbedaan respons berdasarkan jenis kelamin.

Penelitian menggunakan desain *within-subject experiment* yang melibatkan 24 subjek berusia kerja (12 laki-laki dan 12 perempuan) di iklim tropis. Pengukuran dilaksanakan di fasilitas *cold storage* dengan dua kondisi lingkungan: Ruang A (2,58 ± 0,73°C) dan Ruang B (24,42 ± 1,21°C) sebagai kondisi kontrol. Parameter yang diukur meliputi respons fisiologis (suhu timpani (T_{ty}), suhu kulit rata-rata ($\bar{T}_{sk}$), dan denyut jantung (HR), performa kognitif melalui *Dexterity Test, Math Processing Test,* dan *Color Stroop Test*, serta oksigenasi PFC menggunakan *functional Near-Infrared Spectroscopy* (fNIRS) melalui perubahan konsentrasi ΔO_2Hb dan ΔHHb, serta respons subjektif yang meliputi *thermal comfort, thermal sensation, shivering sensation*.

Hasil penelitian menunjukkan bahwa paparan suhu dingin secara signifikan memengaruhi respons fisiologis, yang ditandai penurunan suhu timpani (T_{ty}), suhu kulit rata-rata ($\bar{T}_{sk}$), dan perubahan pola denyut jantung (HR) antar fase. Performa kognitif tidak menunjukkan penurunan yang konsisten; *reaction time* pada beberapa tes justru lebih cepat dalam kondisi dingin, yang diduga dipengaruhi oleh *learning effect* dan peningkatan kewaspadaan sementara. Oksigenasi PFC menunjukkan perbedaan signifikan antar fase, dengan peningkatan ΔO_2Hb pada fase adaptasi dingin dan kecenderungan penurunan selama tugas kognitif dalam kondisi dingin. Analisis berdasarkan jenis kelamin menunjukkan bahwa perempuan melaporkan *thermal sensation* dan *shivering sesation* yang lebih kuat, sementara laki-laki menunjukkan perubahan denyut jantung yang lebih menonjol selama paparan dingin.

Kata Kunci : *cold storage,* respons fisiologis, performa kognitif, oksigenasi *prefrontal cortex,* fNIRS

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ABSTRACT

Workers in cold storage facilities located in tropical climates are at risk of physiological and cognitive impairment due to prolonged exposure to extreme cold temperatures. Individuals adapted to tropical environments are considered more susceptible to cold stress than those from cooler climate, owing to differences in thermoregulatory characteristics. Nevertheles, studies that comprehensively examine the interplay physiological responses, cognitive performance, and pre-frontal cortex (PFC) oxygenation in the context of cold storage work remain limited. This study aimed to analyze the effects of extreme cold exposure on physiological responses, cognitive performance, and PFC oxygenation, and to examine whether these responses differ by sex.

This study employed a within-subject experiment involving 24 working-age participants (12 males and 12 females) accustomed to a tropical climate. Measurements were conducted at a cold storage facility under two environmental conditions: Room A (2.58 ± 0.73°C) and Room B (24.42 ± 1.21°C), the latter seing as the control condition. Outcomes measures included physiological parameters (tympanic temperature (T_{ty}), mean skin temperature ($\bar{T}_{sk}$), and heart rate (HR)), cognitive performance assessed via the Dexterity Test, Math Processing Test, and Color Stroop Test, and PFC oxygenation measured using functional near-infrared spectroscopy (fNIRS) through changes in oxyhemoglobin (ΔO_2Hb) and deoxyhemoglobin (ΔHHb) concentrations. Subjective responses including thermal comfort, thermal sensation, shivering sensation, were recorded.

Results showed that extreme cold exposure significantly affected physiological responses, indicated by reductions in T_{ty}, $\bar{T}_{sk}$, and changes in HR patterns across experimental phases. Cognitive performance did not show a consistent decline; reaction time on several tests were in fact faster under cold conditions, a finding potentially attributable to learning effects and transient alertness. PFC oxygenation differed significantly across phases, with ΔO_2Hb increasing during the Cold Adaptation phase and showing a tendency to decrease during cognitive task performance under cold conditions. Sex-comparisons revealed that female participants reported stronger thermal sensation and shivering sensation, whereas male participants exhibited more pronounced HR changes during cold exposure.

Keywords: *cold storage, physiological responses, cognitive performance, prefrontal cortex oxygenation, fNIRS*