



INTISARI

Dunia industri mengalami transformasi sejak era revolusi industri 1.0 di tahun 1750, dan saat ini telah memasuki era industri 4.0, ditandai dengan semakin banyaknya perkembangan teknologi seperti *Human Robot Collaborative* (HRC) yang merupakan bentuk pengendalian risiko dari segi teknis. Pengalihan sebagian/ seluruh pekerjaan kepada robot merupakan contoh aplikasi hirarki pengendalian risiko yang akan mengurangi beban kerja, sehingga potensi bahaya dan risiko ergonomika dapat dikendalikan atau dieliminasi. Penelitian ini bertujuan untuk mengetahui risiko ergonomika fisik dan persepsi beban mental pekerja dengan interaksi *Human Robot Collaborative* (HRC).

Penelitian ini merupakan penelitian deskriptif kuantitatif non-eksperimental dengan pendekatan *cross-sectional*, yang melibatkan 49 pekerja di industri manufaktur mainan anak, terdiri atas 40 pekerja area perakitan dan 9 pekerja area pengemasan. Subjek penelitian dibagi menjadi kelompok dengan interaksi *collaborative robot* dan kelompok tanpa interaksi *collaborative robot*. Kriteria pemilihan subjek yaitu pekerja yang berinteraksi dengan *Human-Robot Collaborative (HRC)*, dan yang tidak berinteraksi dengan *Human-Robot Collaborative (HRC)* di area perakitan dan pengemasan, serta bersedia berpartisipasi dalam penelitian. Prosedur pengumpulan data meliputi penjelasan penelitian, pengambilan video untuk pengukuran RULA dan RSI, serta pengukuran NASA-TLX. Data dianalisis dengan *Mann-Whitney U test* untuk $p\text{-value} < 0.05$ (tidak berdistribusi normal) dan dengan *t-test* untuk $p\text{-value} > 0.05$ (berdistribusi normal).

Hasil penelitian menunjukkan ada perbedaan signifikan pada beban kerja fisik dan risiko gangguan otot rangka pekerja dengan interaksi *Collaborative Robot* dan pekerja tanpa interaksi *Collaborative Robot* di area perakitan, dengan selisih rata-rata skor RULA yaitu -2.70, $p\text{-value Collaborative Robot} < 0.008$, $p\text{-value non-Collaborative Robot} < 0.001$. Selisih skor RSI tangan kiri yaitu -0.497 dan tangan kanan yaitu -0.758, $p\text{-value RSI tangan kanan untuk Collaborative Robot} 0.001$ dan $p\text{-value RSI tangan kanan untuk non-Collaborative Robot} < 0.001$. Adapun $p\text{-value RSI tangan kiri pada kedua kelompok yaitu} < 0.001$. Di area pengemasan, pekerja dengan interaksi *Collaborative Robot* dan tanpa interaksi *Collaborative Robot* tidak berbeda signifikan, dengan selisih rata-rata skor RULA yaitu -1.00, selisih skor RSI 0.02 (RSI tangan kiri) dan -0.036 (RSI tangan kanan), $p\text{-value RSI tangan kiri pada Collaborative Robot dan} 0.029$ pada RSI tangan kiri pada *non-Collaborative Robot*, dan $p\text{-value RSI tangan kanan pada Collaborative Robot yaitu} 0.019$, dan $p\text{-value RSI tangan kanan pada non-Collaborative Robot} 0.029$. Hasil uji statistik menunjukkan ada perbedaan signifikan pada persepsi beban mental pekerja dengan interaksi *Collaborative Robot* dan pekerja tanpa interaksi *Collaborative Robot* di area Perakitan. Selisih skor NASA-TLX di area perakitan yaitu -20.5, dengan $p\text{-value Collaborative Robot yaitu} 0.450$, dan $p\text{-value non-Collaborative Robot} 0.049$. Sedangkan selisih skor NASA-TLX kedua kelompok di area pengemasan yaitu -5.2, $p\text{-value Collaborative Robot yaitu} 0.366$, dan $p\text{-value non-Collaborative Robot yaitu} 0.336$.

Kata Kunci: *Human Robot Collaborative (HRC)*, *Collaborative Robot*, Risiko gangguan otot rangka, persepsi beban mental.



ABSTRACT

The industrial world has transformed since the era of the First Industrial Revolution in 1750, and has now entered the era of Industry 4.0, characterized by the increasing advancement of technologies such as Human-Robot Collaborative (HRC), which serves as a form of technical risk control. The transfer of partial or entire tasks to robots represents an application of the hierarchy of risk control that reduces workload, thereby enabling ergonomic hazards and risks to be managed or eliminated. This study aims to identify physical ergonomic risks and workers' perceptions of mental workload in relation to Human-Robot Collaborative (HRC).

This research is a non-experimental quantitative descriptive study with a cross-sectional approach, involving 49 workers in a toy manufacturing industry, consisting of 40 workers in the assembly area and 9 workers in the packaging area. The research subjects were divided into two groups: those interacting with collaborative robots and those without such interaction. The inclusion criteria were workers who interacted with Human-Robot Collaboration (HRC) and those who did not, in both assembly and packaging areas, and who were willing to participate in the study. Data collection procedures included research explanation, video recording for RULA and RSI assessment, and NASA-TLX assessment. Data were analyzed using the Mann-Whitney U test for p -values <0.05 (non-normally distributed) and the t-test for p -values >0.05 (normally distributed).

The results revealed significant differences in physical workload and musculoskeletal disorder risks between workers interacting with collaborative robots and those without such interaction in the assembly area. The mean difference in RULA scores was -2.70, with p -values of <0.008 for collaborative robot workers and <0.001 for non-collaborative robot workers. The mean difference in RSI scores for the left hand was -0.497 and for the right hand -0.758, with p -values of 0.001 (right hand, collaborative robot) and <0.001 (right hand, non-collaborative robot). The p -values for left hand RSI in both groups were <0.001 . In the packaging area, no significant differences were found between workers with and without collaborative robot interaction, with a mean RULA score difference of -1.00, RSI score differences of 0.02 (left hand) and -0.036 (right hand), p -value of 0.363 for left hand RSI in collaborative robot workers, 0.029 for left hand RSI in non-collaborative robot workers, and p -values of 0.019 (right hand, collaborative robot) and 0.029 (right hand, non-collaborative robot). Statistical tests further indicated significant differences in workers' perceptions of mental workload between those interacting with collaborative robots and those without in the assembly area. The mean difference in NASA-TLX scores in the assembly area was -20.5, with p -values of 0.450 (collaborative robot) and 0.049 (non-collaborative robot). In the packaging area, the mean difference in NASA-TLX scores between the two groups was -5.2, with p -values of 0.366 (collaborative robot) and 0.336 (non-collaborative robot).

Keywords: Human-Robot Collaboration (HRC), Collaborative Robot, Musculoskeletal Disorder Risk, Mental Workload Perception.