Journal of International Conference Proceedings (JICP)
Vol. 7 No. 2, pp. 707-717, November, 2024
P-ISSN: 2622-0989/E-ISSN: 2621-993X
https://www.ejournal.aibpmjournals.com/index.php/JICP

Effect of Traditional Massage Stimulation on Interleukin 6 (IL-6) Serum Level on Stunted Children

I Nyoman Sueca[1], Sri Sulistyawati Anton[2], Ni Made Diaris[2], Ni Made Umi Kartika Dewi[2], I Gede Agus Krisna Warmayana[3,4], Ni Ketut Sinarsih[2], Ni Wayan Yusi Armini[2]

[1]Department of Hindu Religious Education, Faculty of Dharma Acarya, I Gusti Bagus Sugriwa Hindu State University of Denpasar, Denpasar, Indonesia, 80237
[2]Department of Yoga and Health, Faculty of Brahma Widya, I Gusti Bagus Sugriwa Hindu State University of Denpasar, Denpasar, Indonesia, 80237
[3]Department of Informatics, Faculty of Dharma Duta, I Gusti Bagus Sugriwa Hindu State University of Denpasar, Denpasar, Indonesia, 80237
[4]Graduate School of Humanity-Oriented Science and Engineering, Kindai University, Japan
Correspondence Email: srisulistyawatianton@uhnsugriwa.ac.id
ORCID ID: 0000-0001-8837-2842

ARTICLE INFORMATION

Publication information

Research article

HOW TO CITE
Sueca, I. N., Anton, S. S., Diaris, N. M., Dewi, N. M. U. K., Warmayana, I. G. A. K., Sinarsih, N. K., & Armini, N. W. (2024). Effect of traditional massage stimulation on interleukin 6 (IL-6) serum level on stunted children. *Journal of International Conference Proceedings, 7*(2), 707-717.

DOI:
https://doi.org/10.32535/jicp.v7i2.3844

Received: 21 September 2024
Accepted: 23 October 2024
Published: 25 November 2024

ABSTRACT

Failure to thrive or stunting is a major complication of chronic inflammation and recurrent infections in children. An uncontrolled inflammatory response is associated with stunting syndrome. Mediators that play a role include IL-6. This study aims to determine the effect of traditional massage stimulation on IL-6 serum levels in stunted children aged 12 – 60 months. This study is a quasi-experimental design involving 21 stunted children who received the 15-minute massage treatment three times a week for four weeks. Examination of IL-6 serum levels was carried out using the ELISA method using the Human IL-6 ELISA Kit RAB 0306-1KT Sigma-Aldrich. The serum IL-6 levels before the intervention (60,234pg/ml) had a higher mean value than serum IL-6 after intervention (21,261pg/ml). The paired t-test showed a significant difference in the children's serum IL-6 values before and after the massage intervention ($p<0.000$). It was concluded that traditional massage stimulation reduces Interleukin 6 (IL-6) serum levels in stunted children.

Keywords: Traditional, Massage Stimulation, Infection, IL-6, Stunted

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INTRODUCTION

Globally, Persistent childhood undernutrition is still a significant public health concern, particularly in lower- and middle-income regions where it is deeply intertwined with poverty. Maternal nutrition is a critical determinant of child health, and inadequate dietary intake during pregnancy is strongly linked to low birth weight and intrauterine growth restriction. These early disadvantages often persist into infancy, contributing to poor feeding practices, inadequate nutrient intake, and weakened immunity, which together heighten the risk of recurrent infections. Over time, the combined influence of these biological and socioeconomic factors results in linear growth impairment, commonly known as stunting. Clinically, Stunting describes impaired growth in which a child's height-for-age falls more than two standard deviations under the median value of the World Health Organization growth reference, reflecting prolonged undernutrition and persistent intergenerational health disparities (Vaivada *et al.*, 2020). In 2022, it was estimated that more than 148 million children under the age of five were affected by stunting, representing approximately 22.3% of the global pediatric population and underscoring the persistence of this irreversible public health concern (UNICEF and Ministry of Health of the Republic of Indonesia, 2023). Stunting has been linked to higher mortality rates (UNICEF, World Health Organization and World Bank Group, 2023), long-term cognitive impairments, fewer years of education, subpar academic achievement, reduced adult economic production, and a higher chance of stunting in future generations (Lestari *et al.*, 2024).

Stunting, often presented as a failure to thrive, is among the most critical outcomes of chronic inflammation and recurrent childhood infections. In the earliest stages of life, this condition is largely influenced by the combined effects of poor nutritional intake and frequent exposure to infectious diseases. Poverty intensifies these risks, as limited household resources reduce access to adequate food and contribute to poor sanitation and hygiene, both of which heighten vulnerability to illness and growth impairment. The interaction between malnutrition and repeated infections creates a vicious cycle that not only sustains but also worsens the prevalence of stunting over time (Anton *et al.*, 2022; Gizaw *et al.*, 2022; Mutasa *et al.*, 2022; Anton, Dewi & Adiba, 2023; Lefebo, Kassa & Tarekegn, 2023). Recurrent infections contribute to impaired nutritional status by reducing appetite, disrupting intestinal absorption, and accelerating catabolic processes. Conversely, inadequate dietary intake predisposes children to recurrent infections through alterations in immune system function. This bidirectional relationship underscores the central role of immune dysfunction in growth faltering, as uncontrolled inflammatory responses have been closely linked to the pathophysiology of stunting. Among the inflammatory mediators involved, interleukin-6 (IL-6) has been identified as a key contributor to this syndrome (Thomas & Sing Way, 2023; Widjaja *et al.*, 2023). A study conducted in Egypt in 2017 demonstrated that children experiencing stunting exhibited significantly higher levels of IL-6, TNF-α, and CRP compared to their non-stunted counterparts. These elevations in inflammatory markers are largely attributed to micronutrient deficiencies, which impair immune function by altering cytokine production and overall immune responsiveness. In particular, excessive IL-6 production in malnourished children has been shown to interfere with linear growth by suppressing circulating levels of insulin-like growth factor 1 (IGF-1), a liver-derived hormone that plays a crucial role in mediating the effects of growth hormone and promoting normal growth trajectories (Prendergast *et al.*, 2014; Abd El-Maksoud *et al.*, 2017).

Insulin-like Growth Factor 1 (IGF-1) and Interleukin-6 (IL-6) are two fundamental biomolecules that play central roles in growth regulation, immune function, and overall metabolism. Their dynamic interaction has increasingly been recognized as pivotal in both physiological homeostasis and the pathogenesis of numerous disorders. IL-6, a

pleiotropic cytokine secreted by a variety of cells including fibroblasts, macrophages, and lymphocytes, serves as a key mediator of inflammation and the acute-phase response. It promotes B-cell differentiation, modulates cytokine networks, and exerts wide-ranging effects on immune regulation. Persistently elevated IL-6 levels are characteristic of chronic inflammatory conditions and have been implicated in the development of autoimmune diseases such as rheumatoid arthritis, as well as cardiovascular pathology and malignancies. In contrast, IGF-1 is a peptide hormone structurally similar to insulin, predominantly synthesized in the liver under the stimulation of growth hormone (GH). IGF-1 promotes cellular proliferation, differentiation, and survival, thereby ensuring normal growth and development. Beyond its role in growth, IGF-1 also contributes to glucose homeostasis and has been implicated in aging processes and metabolic dysregulation. The relationship between IL-6 and IGF-1 is complex and multidirectional. Elevated IL-6 during chronic inflammation has been shown to downregulate IGF-1 production by impairing GH signaling at the pituitary–liver axis. Moreover, IL-6 can alter the availability of IGF-1 by upregulating insulin-like growth factor binding protein 1 (IGFBP-1), which sequesters IGF-1 and limits its biological activity. Conversely, IGF-1 has demonstrated anti-inflammatory effects capable of attenuating IL-6–mediated responses. By promoting tissue repair and reducing systemic inflammatory markers, IGF-1 may counteract some of the deleterious consequences of prolonged IL-6 elevation. Evidence also suggests a reciprocal interaction in which IGF-1 can modulate IL-6 signaling, highlighting a feedback mechanism that balances growth and inflammatory pathways. Overall, the interplay between IGF-1 and IL-6 represents a finely tuned equilibrium between anabolic growth processes and catabolic inflammatory responses. Disruption of this balance may contribute to diverse clinical conditions, including metabolic syndrome, obesity, and growth disorders. Understanding this bidirectional relationship provides a valuable framework for exploring therapeutic interventions aimed at modulating IGF-1 and IL-6 activity to restore homeostasis and mitigate disease progression. Future research is expected to elucidate these mechanisms further, potentially guiding the development of novel treatment strategies for conditions characterized by growth impairment and chronic inflammation (De Benedetti *et al.*, 1997b; Rozing *et al.*, 2009; Walters & Griffiths, 2009; Bakker & Jaspers, 2015; Wong *et al.*, 2016)

Massage potentially improves the inflammatory process, facilitates early recovery, and relieves pain from muscle injury through changing signals involved in the inflammatory process (Waters-Banker, Esther E. Dupont-Versteegden, *et al.*, 2014). The stimulation mechanism of massage affects the child's immune system by inhibiting the regulation of the release of pro-inflammatory cytokines TNF-α and IL-6 by macrophages (Trisna-Windiani *et al.*, 2015). Other research also shows that aromatherapy massage has immunological benefits (Kuriyama *et al.*, 2005).

LITERATURE REVIEW

According to WHO growth standards, stunting occurs when a child’s length or height-for-age falls significantly below the expected range, falls below –2 standard deviations, serving as a key indicator of chronic malnutrition. It represents a progressive process that develops in response to long-standing biological disruptions, particularly undernutrition and recurrent infections, occurring during the critical period of linear bone growth. The onset of stunting can be traced from the intrauterine environment and extends through the first two years of life, a period commonly referred to as the “first 1,000 days,” which is widely recognized as the most crucial window for child growth and development. (Ministry of Health of the Republic of Indonesia, 2020). Childhood stunting is strongly associated with poverty and is widely utilized as a population-based indicator to assess nutritional adequacy across countries. When stunting occurs during the early

years of life, it often results in irreversible growth impairment, ultimately leading to short stature in adulthood. A growing body of evidence from multiple settings demonstrates that children who experience malnutrition severe enough to induce stunting in early life are more likely to exhibit cognitive deficits during school age, which can adversely affect learning capacity and academic performance. Beyond its immediate effects on physical growth, stunting compromises long-term developmental outcomes and is therefore considered a critical marker for estimating the proportion of children worldwide who fail to achieve their full developmental potential (Hurley, Yousafzai and Lopez-Boo, 2016).

Interleukin-6 (IL-6) is a cytokine with broad biological activity, involved in the regulation of inflammatory processes, immune system function, and blood cell formation. It can be secreted by several cell types, such as macrophages, endothelial and glial cells, keratinocytes, and fibroblasts. Beyond its contribution to hematopoiesis and the acute-phase reaction, IL-6 also influences metabolic pathways and supports neurogenesis. Owing to this wide spectrum of activity, IL-6 is essential for maintaining physiological stability; however, when its regulation is disturbed, it has been linked to the onset and progression of multiple diseases (Spooren *et al.*, 2011). Interleukin-6 (IL-6) has a dual nature, acting not only as a pro-inflammatory cytokine but also as an anti-inflammatory myokine. In the early stages of inflammation, IL-6 released from injured tissues enters systemic circulation and promotes hepatic synthesis of acute-phase proteins, including CRP, SAA, fibrinogen, haptoglobin, and α1-antichymotrypsin. Increased IL-6 concentrations, however, are correlated with diminished production of proteins like albumin, transferrin, and fibronectin. In addition, IL-6 plays a key role in iron homeostasis by inducing hepcidin, a regulatory peptide that inhibits ferroportin 1—the principal iron exporter—thereby lowering circulating iron levels. (Tanaka, Narazaki & Kishimoto, 2014).

Interleukin-6 (IL-6) is produced under various pathological conditions, most notably during infection and inflammation. In infectious states, IL-6 is secreted at the lesion site and then circulates systemically, transmitting inflammatory signals throughout the body. Pathogen recognition occurs as PRRs on innate immune cells, such as monocytes and macrophages, bind to PAMPs. This interaction triggers intracellular signaling cascades, with NF-κB being the principal pathway responsible for promoting the transcription of inflammatory cytokines, notably IL-6, TNF-α, and IL-1β. TNF-α and IL-1β further reinforce this response by stimulating additional transcription factors that upregulate IL-6 expression. Apart from infection, IL-6 is also released following tissue injury. In such cases, damage-associated molecular patterns (DAMPs) originating from necrotic or apoptotic cells act as endogenous alarm signals that sustain the inflammatory response. Examples of these molecules include mitochondrial DNA (mtDNA), high-mobility group box 1 (HMGB1), and S100 proteins. Mitochondrial DNA, for instance, activates Toll-like receptor 9 (TLR9), leading to NF-κB signaling, whereas HMGB1 interacts with TLR2, TLR4, and the receptor for advanced glycation end-products (RAGE), thereby propagating inflammatory pathways that promote further IL-6 production (Tanaka, Narazaki & Kishimoto, 2014). Insulin-like growth factor-1 (IGF-1) is a hormone predominantly synthesized in the liver. As a key growth mediator, IGF-1 plays a central role in promoting and regulating growth processes (De Benedetti *et al.*, 1997a). Reduced concentrations of IGF-1 have been observed in individuals experiencing states of malnutrition (Thissen, Ketelslegers & Underwood, 1994; Scacchi, Pincelli & Cavagnini, 2003; Bartz *et al.*, 2014) and systemic inflammation (Fan *et al.*, 1995; De Benedetti *et al.*, 1997a; Difedele *et al.*, 2005). Beyond inadequate nutrition, prolonged exposure to chronic inflammation during fetal development and the early postnatal period is a significant determinant of stunting in children. Ongoing inflammatory activity can inhibit the synthesis of essential growth mediators such as insulin-like growth factor-1 (IGF-1)

and interfere with the growth hormone (GH) axis from an early age, ultimately impairing normal patterns of linear growth (Prendergast *et al.*, 2014).

Massage is regarded as one of the oldest healing practices known to humankind. Often referred to as "touch therapy," it encompasses a range of manual techniques such as rubbing, pressing, kneading, pinching, tapping, and vibrating specific parts of the body with the aim of promoting health and physical well-being. The therapeutic effects of massage extend beyond the physical domain, offering psychological and emotional benefits that contribute to overall wellness (Ministry of Health of the Republic of Indonesia, 2016). Massage stimulation is a natural form of touch for children, which may involve gentle rubbing, kneading, or pressing. In Indonesia, massage is regarded as a cultural health practice that has been preserved and transmitted across generations. For children, massage functions as a holistic form of stimulation that incorporates verbal communication, visual interaction, auditory input, tactile sensation, and kinesthetic movement, reflecting the parents' affection toward their child. As part of traditional medicine, massage is considered an effective approach to improving child health. This practice involves the manual application of touch, through rubbing, pressing, squeezing, or vibrating the body, to provide both stimulating and relaxing effects. Physiologically, massage enhances blood circulation, supports the flow of lymphatic vessels and lymph nodes, and strengthens the function of body organs, thereby contributing to the maintenance of overall health. (Ministry of Health of the Republic of Indonesia, 2021).

RESEARCH METHOD

This research utilized a quasi-experimental design with pre-test and post-test measurements. The participants were 21 children identified as stunted, characterized by a height-for-age z-score of less than minus two, all of whom met the predetermined inclusion criteria. Prior to the intervention, venous blood samples of three cubic centimeters were collected from each child by trained medical laboratory personnel. The intervention involved the administration of massage therapy, delivered three times per week over a four-week period. Each session lasted approximately 15 minutes. To maintain the consistency and reliability of the intervention, the research team directly administered the massage sessions to the children. All procedures were carefully documented through photographs and written intervention notes. Venous blood samples were drawn after the four-week intervention to assess serum IL-6 concentrations in the post-test phase. The evaluation utilized the Enzyme-Linked Immunosorbent Assay (ELISA) method with the Human IL-6 Kit RAB 0306-1KT (Sigma-Aldrich) at the HUM-RC Laboratory of Hasanuddin University Hospital. The protocol was reviewed and approved by the Dhyana Pura University Ethics Committee (Approval No. 000823/KEP/2024).

RESULTS

Table 1. Changes in Serum IL-6 Levels Pre and Post Intervention (*n*=21)

Parameter	Min.	Max.	M	SD	p-value
IL-6 Pre Intervention	2.657	99.633	60.234	27.143	0.000*
IL-6 Post Intervention	1.849	`54.562	21.261	13.223	

Note. M = Mean, *SD* = Standard Deviation, *Paired t-test

Table 1 presents the changes in serum Interleukin-6 (IL-6) levels in children following the massage stimulation intervention. Prior to the intervention, the mean serum IL-6 concentration (mean ± SD) was 60,234 ± 27,143. After four weeks of massage

stimulation, the mean value decreased markedly to 21,261 ± 13,223. Statistical analysis using the paired t-test demonstrated a significant difference between pre-intervention and post-intervention IL-6 levels, indicating that massage stimulation effectively reduced systemic inflammation in the study population.

DISCUSSION

According to the current World Health Organization growth standards, inadequate height-for-age, weight-for-age, and weight-for-height are indicators of poor growth in children. Stunting, a major growth disorder, arises from a combination of chronic undernutrition, recurrent infections, and insufficient psychosocial stimulation during critical periods of development (Anton, Dewi & Adiba, 2023). The pathogenic mechanisms associated with malnutrition extend beyond simple nutrient deficiencies and encompass a complex interplay of biological disruptions that contribute to immune dysfunction. Impaired intestinal absorption reduces the bioavailability of essential macro- and micronutrients, thereby limiting the substrates required for optimal immune cell function and tissue repair. At the same time, malnutrition is accompanied by an elevated metabolic demand, as the body attempts to compensate for energy deficits while simultaneously mounting responses to infectious challenges. Dysregulation of the growth hormone axis and the hypothalamic–pituitary–adrenal (HPA) axis further exacerbates these effects, as alterations in hormonal signaling impair linear growth, disrupt metabolic homeostasis, and weaken host defenses. Moreover, malnourished children experience heightened susceptibility to recurrent infections, which not only deplete nutrient reserves but also perpetuate chronic inflammation. Together, these interrelated processes create a vicious cycle in which malnutrition undermines immune competence, and immune dysfunction in turn worsens the risk of infection and growth failure, ultimately contributing to stunting and long-term health consequences (Bourke, Berkley & Prendergast, 2016). Tumor necrosis factor-alpha (TNF-α), interleukins (e.g., IL-6, IL-10) and interferon-gamma (IFN-γ) are cell-signaling cytokines that, in response to infection, activate and drive immune cell differentiation (Arango Duque and Descoteaux, 2014). In response to infection or inflammation, IL-6 is thought to be the primary inducer of hepatocyte synthesis of acute-phase proteins (Pepys and Hirschfield, 2003). Infection rates among malnourished children are higher than those of their peers (Platts-Mills *et al.*, 2017).

This study demonstrated that children with stunting exhibited elevated levels of IL-6. These findings are consistent with previous research conducted in Egypt in 2017, which reported that stunted children had significantly higher concentrations of IL-6, TNF-α, and CRP compared with their non-stunted peers. Such increases in pro-inflammatory cytokines are closely linked to micronutrient deficiencies, which compromise immune function by altering immune responses and cytokine production. In particular, excessive IL-6 production in malnourished children can interfere with linear growth by reducing circulating levels of insulin-like growth factor 1 (IGF-1), a liver-derived hormone that mediates the action of growth hormone and plays a central role in promoting normal growth and development (Prendergast & Humphrey, 2014; Abd El-Maksoud *et al.*, 2017).

Following four weeks of massage stimulation, serum IL-6 levels in the children showed a marked reduction. This finding suggests that massage may exert beneficial effects on the inflammatory process by modulating signaling pathways involved in immune regulation. Beyond its role in lowering pro-inflammatory mediators, massage therapy has also been reported to facilitate early recovery and alleviate pain associated with muscle injury, highlighting its broader potential as a supportive intervention for improving health outcomes in children (Waters-Banker, Esther E. Dupont-Versteegden, *et al.*, 2014). The mechanism of massage stimulation is thought to influence the child's immune system by

modulating macrophage activity, specifically through the suppression of pro-inflammatory cytokine release, including TNF-α and IL-6 (Trisna-Windiani *et al.*, 2015). Other studies also show that aromatherapy massage has immunological benefits (Kuriyama *et al.*, 2005). A study in 2022 also showed similar results, where massage intervention was able to reduce serum IL-6 levels (Budiani & Somoyani, 2022).
Massage therapy, which involves applying manual pressure to soft tissues and muscles, is increasingly recognized for its therapeutic benefits in both traditional practices and modern healthcare. A key physiological effect is the suppression of Interleukin-6 (IL-6) levels in circulation. This cytokine, produced by multiple cell types such as fibroblasts, endothelial cells, and immune cells, acts as a regulator of immune activity by mediating both inflammatory and anti-inflammatory pathways. Under normal circumstances, IL-6 supports immune coordination and assists in the process of tissue regeneration. When elevated for prolonged periods, however, IL-6 contributes to chronic inflammation and is strongly associated with conditions such as rheumatoid arthritis, cardiovascular disease, and metabolic syndrome. Its production can be stimulated by acute stress, infection, or tissue damage, leading to the release of additional pro-inflammatory cytokines and promoting the hepatic synthesis of acute-phase proteins, including C-reactive protein (CRP). Persistently high levels of IL-6 reinforce a chronic inflammatory state, thereby accelerating disease progression (Tanaka, Narazaki & Kishimoto, 2014; Rose-John, 2020).

One of the primary mechanisms through which massage therapy may influence IL-6 levels is its effect on the autonomic nervous system. By stimulating the parasympathetic nervous system, massage promotes the body's "rest-and-digest" response, counteracting the sympathetic nervous system, which is associated with the "fight-or-flight" reaction and is known to exacerbate stress and inflammation. Under conditions of stress, activation of the hypothalamic–pituitary–adrenal (HPA) axis leads to the release of cortisol and other stress-related hormones. Elevated cortisol concentrations can, in turn, enhance the production of pro-inflammatory cytokines such as IL-6. Massage therapy helps to reduce cortisol secretion by fostering relaxation and dampening HPA axis hyperactivity. Consequently, this reduction in cortisol not only decreases systemic stress but also contributes to the downregulation of IL-6 production, resulting in lower circulating IL-6 levels (Sharpe *et al.*, 2007; Field, 2014). The primary mechanisms of massage therapy involve elevated blood flow to the massaged area, accompanied by increases in skin and muscle warmth (Mori *et al.*, 2004; Weerapong, Hume & Kolt, 2005).

A growing body of evidence indicates that massage therapy can influence cytokine production, including both pro-inflammatory and anti-inflammatory mediators such as IL-6. Beyond its well-known role in promoting relaxation and reducing muscle tension, massage exerts measurable effects on physiological pathways related to inflammation and immune regulation. The mechanical manipulation of tissues enhances blood circulation and lymphatic drainage, processes that are fundamental for maintaining tissue health and modulating inflammation. Improved circulation facilitates the delivery of oxygen and essential nutrients to target tissues, while simultaneously promoting the clearance of metabolic by-products and inflammatory mediators. These mechanisms contribute to a reduction in local inflammation and accelerate tissue healing. In addition, massage-induced stimulation of the lymphatic system supports the removal of excess interstitial fluid that often contains inflammatory cytokines, including IL-6. By decreasing the concentration of such mediators, massage therapy may mitigate both localized and systemic inflammatory responses. This immunomodulatory effect highlights the therapeutic potential of massage not only as a traditional practice for well-being, but also as a complementary intervention for managing inflammation-related conditions. Through its combined mechanical and physiological actions, massage supports tissue repair, strengthens immune regulation, and contributes to improved overall health outcomes

(Crane *et al.*, 2012; Waters-Banker, Esther E Dupont-Versteegden, *et al.*, 2014; White *et al.*, 2020).

CONCLUSION

The present study demonstrated that traditional massage stimulation significantly reduced serum Interleukin-6 (IL-6) levels in stunted children. This finding provides evidence that massage, beyond its cultural and traditional significance, has measurable physiological effects that can contribute to the reduction of systemic inflammation. By lowering IL-6, massage may help to mitigate one of the biological pathways underlying growth impairment, thereby supporting healthier developmental outcomes in children affected by stunting. As a health practice passed down through generations, traditional massage represents a valuable component of Indonesia's cultural heritage that also carries modern therapeutic relevance. Its integration into child health strategies may serve as a complementary approach alongside nutritional and medical interventions. Emphasizing traditional massage in community health programs has the potential to strengthen holistic child care practices, enhance family engagement, and promote sustainable approaches to improving child health in Indonesia.

ACKNOWLEDGMENT

This work received funding from the DIPA Research Grant, I Gusti Bagus Sugriwa Hindu State University (No. 583/2024). The authors thank the Blahbatuh 2 Health Centre, Gianyar Regency, for facilitating the study, and the Hasanuddin University Medical Research Centre (HUM-RC) for providing laboratory support and equipment for sample testing.

DECLARATION OF CONFLICTING INTERESTS

The authors confirm that there are no financial or non-financial conflicts of interest associated with the research, authorship, or dissemination of this article.

REFERENCES

Abd El-Maksoud, A. M., et al. (2017). Evaluation of pro-inflammatory cytokines in nutritionally stunted Egyptian children. *Egyptian Pediatric Association Gazette, 65*(3), 80–84. https://doi.org/10.1016/j.epag.2017.04.003

Anton, S. S., et al. (2022). Effect of rebon shrimp-based supplementary feeding on height of stunted children. *Journal of International Conference Proceedings, 5*(1), 236–241. https://doi.org/10.32535/jicp.v5i1.1473

Anton, S. S., Dewi, N. M. U. K., & Adiba, I. G. (2023). Kajian determinan stunting pada anak di Indonesia. *Jurnal Yoga dan Kesehatan, 6*(2), 201–217.

Arango Duque, G., & Descoteaux, A. (2014). Macrophage cytokines: Involvement in immunity and infectious diseases. *Frontiers in Immunology, 5*, 491. https://doi.org/10.3389/fimmu.2014.00491

Bakker, A. D., & Jaspers, R. T. (2015). IL-6 and IGF-1 signaling within and between muscle and bone: How important is the mTOR pathway for bone metabolism? *Current Osteoporosis Reports, 13*(3), 131–139. https://doi.org/10.1007/s11914-015-0264-1

Bartz, S., et al. (2014). Severe acute malnutrition in childhood: Hormonal and metabolic status at presentation, response to treatment, and predictors of mortality. *The Journal of Clinical Endocrinology & Metabolism, 99*(6), 2128–2137.

De Benedetti, F., et al. (1997a). Interleukin 6 causes growth impairment in transgenic mice through a decrease in insulin-like growth factor-I: A model for stunted growth in children with chronic inflammation. *The Journal of Clinical Investigation, 99*(4), 643–650.

De Benedetti, F., et al. (1997b). Interleukin 6 causes growth impairment in transgenic mice through a decrease in insulin-like growth factor-I: A model for stunted growth in children with chronic inflammation. *Journal of Clinical Investigation, 99*(4), 643–650. https://doi.org/10.1172/JCI119207

Bourke, C. D., Berkley, J. A., & Prendergast, A. J. (2016). Immune dysfunction as a cause and consequence of malnutrition. *Trends in Immunology, 37*(6), 386–398. https://doi.org/10.1016/j.it.2016.04.003

Budiani, N. N., & Somoyani, N. K. (2022). Effect of back massage using frangipani aromatherapy on interleukin-6 (IL-6) levels and pain labor intensity. *International Journal of Health Sciences, 6*, 121–133. https://doi.org/10.53730/ijhs.v6ns10.13343

Crane, J. D., et al. (2012). Massage therapy attenuates inflammatory signaling after exercise-induced muscle damage. *Science Translational Medicine, 4*(119). https://doi.org/10.1126/scitranslmed.3002882

Difedele, L. M., et al. (2005). Tumor necrosis factor α blockade restores growth hormone signaling in murine colitis. *Gastroenterology, 128*(5), 1278–1291.

Fan, J., et al. (1995). Modulation of inflammation-induced changes in insulin-like growth factor (IGF)-I and IGF binding protein-1 by anti-TNF antibody. *Shock, 4*(1), 21–26.

Field, T. (2014). Massage therapy research review. *Complementary Therapies in Clinical Practice, 20*(4), 224–229. https://doi.org/10.1016/j.ctcp.2014.07.002

Gizaw, Z., et al. (2022). Stunting among children aged 24–59 months and associations with sanitation, enteric infections, and environmental enteric dysfunction in rural northwest Ethiopia. *Scientific Reports, 12*(1), 1–11. https://doi.org/10.1038/s41598-022-23981-5

Hurley, K. M., Yousafzai, A. K., & Lopez-Boo, F. (2016). Early child development and nutrition: A review of the benefits and challenges of implementing integrated interventions. *Advances in Nutrition, 7*(2), 357–363. https://doi.org/10.3945/an.115.010363

Kuriyama, H., et al. (2005). Immunological and psychological benefits of aromatherapy massage. *Evidence-Based Complementary and Alternative Medicine, 2*(2), 179–184. https://doi.org/10.1093/ecam/neh087

Lefebo, B. K., Kassa, D. H., & Tarekegn, B. G. (2023). Factors associated with stunting: Gut inflammation and child and maternal-related contributors among under-five children in Hawassa City, Sidama Region, Ethiopia. *BMC Nutrition, 9*(1), 1–8. https://doi.org/10.1186/s40795-023-00701-4

Lestari, E., et al. (2024). Stunting and its association with education and cognitive outcomes in adulthood: A longitudinal study in Indonesia. *PLoS ONE, 19*(5), 1–18. https://doi.org/10.1371/journal.pone.0295380

Ministry of Health of the Republic of Indonesia. (2016). *Pedoman pijat tradisional Indonesia*. Kementerian Kesehatan RI.

Ministry of Health of the Republic of Indonesia. (2020). *Peraturan Menteri Kesehatan RI No. 2 Tahun 2020 tentang standar antropometri anak*. Ministry of Health of the Republic of Indonesia.

Ministry of Health of the Republic of Indonesia. (2021). *Kurikulum modul: TOT peningkatan kapasitas bidan dalam pelayanan pijat baduta untuk tumbuh kembang di FKTP*. Kementerian Kesehatan RI.

Mori, H., et al. (2004). Effect of massage on blood flow and muscle fatigue following isometric lumbar exercise. *Medical Science Monitor, 10*(5), CR173–CR178.

Mutasa, K., et al. (2022). Stunting status and exposure to infection and inflammation in early life shape antibacterial immune cell function among Zimbabwean children.

Frontiers in Immunology, 13, 899296. https://doi.org/10.3389/fimmu.2022.899296

Pepys, M. B., & Hirschfield, G. M. (2003). C-reactive protein: A critical update. *The Journal of Clinical Investigation, 111*(12), 1805–1812. https://doi.org/10.1172/JCI18921

Platts-Mills, J. A., et al. (2017). Association between enteropathogens and malnutrition in children aged 6–23 months in Bangladesh: A case-control study. *The American Journal of Clinical Nutrition, 105*(5), 1132–1138.

Prendergast, A. J., et al. (2014). Stunting is characterized by chronic inflammation in Zimbabwean infants. *PLoS ONE, 9*(2), e86928. https://doi.org/10.1371/journal.pone.0086928

Prendergast, A. J., & Humphrey, J. H. (2014). The stunting syndrome in developing countries. *Paediatrics and International Child Health, 34*(4), 250–265. https://doi.org/10.1179/2046905514Y.0000000158

Rose-John, S. (2020). Interleukin-6 signalling in health and disease. *F1000Research, 9*. https://doi.org/10.12688/f1000research.26058.1

Rozing, M. P., et al. (2009). Human insulin/IGF-1 and familial longevity at middle age. *Aging, 1*(8), 714–722. https://doi.org/10.18632/aging.100071

Scacchi, M., Pincelli, A. I., & Cavagnini, F. (2003). Nutritional status in the neuroendocrine control of growth hormone secretion: The model of anorexia nervosa. *Frontiers in Neuroendocrinology, 24*(3), 200–224.

Sharpe, P. A., et al. (2007). A randomised study of the effects of massage therapy compared to guided relaxation on well-being and stress perception among older adults. *Complementary Therapies in Medicine, 15*(3), 157–163. https://doi.org/10.1016/j.ctim.2007.01.004

Spooren, A., et al. (2011). Interleukin-6, a mental cytokine. *Brain Research Reviews, 67*(1–2), 157–183.

Tanaka, T., Narazaki, M., & Kishimoto, T. (2014). IL-6 in inflammation, immunity, and disease. *Cold Spring Harbor Perspectives in Biology, 6*(10), a016295.

Thissen, J.-P., Ketelslegers, J.-M., & Underwood, L. E. (1994). Nutritional regulation of the insulin-like growth factors. *Endocrine Reviews, 15*(1), 80–101.

Thomas, D., & Sing, W. (2023). The role of chronic inflammation in stunting: A systematic literature review. *Scientific Journal of Pediatrics, 1*(2), 41–47. https://doi.org/10.59345/sjped.v1i2.68

Trisna-Windiani, I. G. A., et al. (2015). The effect of massage stimulation to reduction of tumor necrotic factor-alfa (TNF-α) and interleukin-6 (IL-6) in preterm, low birth weight appropriate with gestational age infants. *Indonesia Journal of Biomedical Science, 9*(2), 1–20. https://doi.org/10.15562/ijbs.v9i2.15

UNICEF & Ministry of Health of the Republic of Indonesia. (2023). *Towards a future in Indonesia without child undernutrition*. Ministry of Health of the Republic of Indonesia.

UNICEF, World Health Organization, & World Bank Group. (2023). *Levels and trends in child malnutrition: UNICEF/WHO/World Bank Group joint child malnutrition estimates: Key findings of the 2023 edition*. World Health Organization.

Vaivada, T., et al. (2020). Stunting in childhood: An overview of global burden, trends, determinants, and drivers of decline. *American Journal of Clinical Nutrition, 112*, 777S–791S. https://doi.org/10.1093/ajcn/nqaa159

Walters, T. D., & Griffiths, A. M. (2009). Mechanisms of growth impairment in pediatric Crohn's disease. *Nature Reviews Gastroenterology & Hepatology, 6*(9), 513–523. https://doi.org/10.1038/nrgastro.2009.124

Waters-Banker, C., Dupont-Versteegden, E. E., et al. (2014). Investigating the mechanisms of massage efficacy: The role of mechanical immunomodulation. *Journal of Athletic Training, 49*(2), 266–273. https://doi.org/10.4085/1062-6050-49.2.25

Weerapong, P., Hume, P. A., & Kolt, G. S. (2005). The mechanisms of massage and

effects on performance, muscle recovery and injury prevention. *Sports Medicine, 35*(3), 235–256. https://doi.org/10.2165/00007256-200535030-00004

White, G. E., et al. (2020). Massage therapy modulates inflammatory mediators following sprint exercise in healthy male athletes. *Journal of Functional Morphology and Kinesiology, 5*(1), 1–12. https://doi.org/10.3390/jfmk5010009

Widjaja, N. A., et al. (2023). Effect of lactoferrin in oral nutrition supplement (ONS) towards IL-6 and IL-10 in failure to thrive children with infection. *F1000Research, 12*, 1–35. https://doi.org/10.12688/f1000research.130176.3

Wong, S. C., et al. (2016). Growth and the growth hormone-insulin like growth factor 1 axis in children with chronic inflammation: Current evidence, gaps in knowledge, and future directions. *Endocrine Reviews, 37*(1), 62–110. https://doi.org/10.1210/er.2015-1026

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