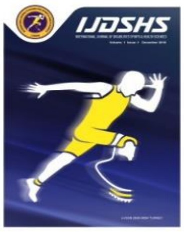

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RESEARCH ARTICLE

# Assessment of Alterations in Gait Parameters of Chronic Total Knee Arthroplasty – An Observational Study

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**Abstract**
**Purpose of the Study:** This research investigates postoperative gait alterations in individuals aged 50 and above who underwent total knee arthroplasty (TKA) at least one year ago. The study aims to fill existing gaps in literature by comprehensively assessing various gait parameters and understanding the persistent changes in mobility following TKA. **Materials and Methods:** Conducted as an observational study, 30 TKA subjects were assessed using Kinovea software for gait parameters, including cadence, speed, step length, step width, stride length, and knee flexion angle. Statistical analysis with MS Excel compared obtained values with established norms. **Results:** Significant gait parameter alterations were observed in post-TKA subjects. These changes include decreased cadence, walking speed, step length, and stride length, along with variations in knee flexion angle. Approximately 36.67% of participants exhibited alterations in these parameters, highlighting the need for further understanding of mobility challenges post-TKA. **Conclusion:** This study contributes vital insights into the persistent impact of TKA on gait parameters, emphasizing the complexity of postoperative mobility changes. The observed alterations highlight the importance of tailored rehabilitation programs to enhance functional independence and address long-term gait concerns in this patient population.

**Keywords**
Gait, Total Knee Arthroplasty, Gait Parameters, Physiotherapy

## INTRODUCTION

Gait, in simple terms, refers to the way a person walks (Kharb et al. 2011). When individuals walk, their bodies must bear the load, provide assistance for movement, and maintain balance to achieve the desired walking pattern. Proper body posture is crucial to align with this gait. Due to the significant influence of mobility on a patient's autonomy, efforts are made to preserve this capability despite substantial limitations (Rana et al. 2016). Therefore, studying the gait cycle which represents a cyclic pattern of movement during walking becomes important (Kharb et al. 2011). Gait cycle starts with one foot's heel striking the ground and ends when the same heel touches the ground again (Levangie et al. 2011).

The knee, one of the most injured joints in the human body, bears a significant portion of the total body weight during walking. When the knee joint is severely damaged and conventional treatments are ineffective, total knee arthroplasty (TKA) is necessary. TKA is a cost-effective and reliably successful procedure, particularly for arthritis, the most common indication (Pachore et al. 2013). It provides reliable outcomes for grade 4 degenerative osteoarthritis, alleviating pain and

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improving the quality of life (Broatzman et al. 2011; Insall et al. 1985; Varacallo et al. 2018).

Research indicates that patients with osteoarthritis experience gait parameter alterations due to pain, stiffness, and reduced range of motion (Rana et al. 2016). These changes persist after TKA, although inconsistencies in results exist, indicating a need for further investigation (McClelland, 2007). As the body is a kinetic chain, the knee serves as a connection between the hip and ankle joints (Karandikar and Vargas, 2011). Increased severity of osteoarthritis leads to biomechanical changes in the hip, knee, and ankle joints (Astephen et al. 2008).

Surgeons typically use specific criteria as indications for TKA, considering factors such as severe daily pain, frequent rest pain, daily transfer pain, and extensive joint space damage observed in radiographs (Mancuso et al. 1996). The knee joint, divided into three compartments (medial, lateral, and patellofemoral), is commonly treated with TKA for grade 4 osteoarthritis, where all three compartments are replaced with monolithic femoral and tibial components. Single-compartmental conditions can be managed through partial knee arthroplasty (PKA) using various implants (Lange et al. 2017; Varacallo 2018).

Knee implants can be either cemented or non-cemented with most being cemented, while others attach directly to the bone without cement. Non-cemented designs rely on bone growth into textured or coated implant surfaces, often modified with hydroxyapatite to enhance bonding. Stainless steel is not used in knee replacement implants due to its limited ability to withstand corrosion over time within the human body. It is better suited for temporary applications such as fracture plates and screws. While cobalt-chromium alloys, tough and biocompatible, are widely used despite potential metal particle release (Aherwar et al. 2016). Titanium and its alloys, including Ti6Al4V, are popular for knee implants due to their biocompatibility, corrosion resistance, and lower density, mimicking natural joints and reducing complications. Tantalum, a flexible and biocompatible pure metal, is used in Trabecular Metal for bone in-growth (Levine et al. 2007). Polyethylene, common in tibial and patellar components, has improved wear resistance through materials like Ultra Highly Cross-Linked Polyethylene (UHXLPE) (Chakrabarty et al. 2015). Zirconium alloy, combined with an all-plastic tibial component, offers a potentially longer-lasting and biocompatible alternative, addressing concerns for nickel-allergic patients. Oxinium is oxidized zirconium. It combines ceramic and metallic properties, providing durability with reduced friction, potentially outlasting traditional materials like cobalt-chromium alloys in knee implants (Mehjabeen et al. 2018). Material choice depends on patient needs, preferences, and surgeon expertise, with continuous advancements in the field (Carr et al. 2009).

Physiotherapy after TKA is crucial for preventing complications arising from bedrest and regaining joint mobility and muscle strength. It includes teaching safe ambulation and transfers, reducing pain and swelling in the early post-surgery phase, and improving joint range of motion, muscle strength and endurance. Physiotherapy aims to boost mood, reduce anxiety, and restore full knee function for a return to normal activities, ensuring functional independence. While physiotherapy typically lasts for three months, patients are then gradually transitioned to a home-based protocol. However, as patients become more comfortable with daily activities, many discontinue the exercise routine, emphasizing the need to study changes in gait parameters 1 to 2 years after total knee arthroplasty (Hardy et al 2007).

## MATERIALS AND METHODS

This was an observational study carried out in which alterations in gait parameters after total knee arthroplasty were assessed.

***Participants***

Our study, planned as a cross sectional research, included 30 subjects with the age of 50 years and above and who have undergone TKA at least 1 year ago (Figure1). Individuals were chosen based on specified criteria for inclusion and exclusion which is given below. 2 subjects aged between 55-59, 7 subjects aged between 60-64 years, 12 subjects aged between 65-69 years, 9 subjects aged between 70-75 years (Table 1). Out of 30, 19 subjects were male and 11 subjects were females. Out of 30, 6 had bilateral TKA, 15 had right and 9 had left TKA done. Out of 30, 4 subjects had a BMI ranging betweeb 20-24 (normal BMI), 5 subjects had BMI between 25-29 (overweight), 12 subjects had a BMI between 30-

34 (obese grade 1) (Table 1). Average height of the participant males was 165 cm and that of female participants was 152 cm. Out of 30, 6 subjects had undergone TKA 12 months ago, 9 had undergone 12-18 months ago, 8 subjects had undergone TKA 18-24 months, 7 subjects had undergone TKA 24-30 months ago at the time of assessment.

The participating subjects were informed about the study protocol, their rights, and the associated risks of participation before providing written informed consent. This observation was conducted on humans. The observational study was accepted by Institutional Human Ethics Committee of Krishna Institute of Medical Sciences, "Deemed to be University," Karad (Protocol number-617/2022-23). The study was carried out in accordance with the recommendations of the Declaration of Helsinki. Additional precautions were taken by the investigator(s) to protect the volunteers in this study. The selected subjects were asked to walk for a fixed distance of 3 meters and the time required to complete the distance was recorded using a stopwatch.

***Data collection tool***

Software named kinovea was used to measure the gait parameters. Kinovea serves as a specialized video analysis tool tailored for sports. It offers features such as capturing, slowing down, comparing, interpreting, and measuring motion in videos. The tool includes a chronometer for measuring time spans and tools like line, angle, and goniometer for measuring distances and angles. Precision is enhanced by the ability to zoom in, and measurements are conducted with subpixel accuracy, ensuring detailed and accurate analysis. Cadence was measured by counting the number of steps walked per minute by slowing the frame rate and counting the steps covered by the participants. Speed was calculated by dividing the distance covered by the subject by the time taken to cover it. Step length was measured by pausing the video and then by using the tool 'line' in the software, the distance between the heel of one foot to the heel of the other foot was measured. Stride length was calculated by multiplying the step width by 2. Knee flexion angle during early swing phase of the gait cycle was measured by pausing the video at early swing phase of the gait cycle and the tool 'angle' available in the kinovea software was used where it uses goniometer to measure the angle (Puig et al. 2019). Subjects were asked to dip feet in the water and walk. Step width was measured at the assessment place by measuring the horizontal distance between midpoint of the heel of one foot to the corresponding point of another foot from the obtained footprints. The obtained values were compared with the normal standard values.

***Inclusion criterion***

Subjects post total knee arthroplasty.
Subjects who have undergone TKA at least one year ago.
Subjects with unilateral or bilateral TKA.
Both male and female subjects.
Subjects with age above 50 years.

***Exclusion criteria:***

Any other major injury to lower limb

***Statistical analysis***

It was done using MS excel and instat statistics software. One sample t-test was used to find out the p values of obtained findings. It was done using MS excel and instat statistics software. One sample t-test was used to find out the p values of obtained findings. The findings are summarized in a table/graph format. The analysis was done using the kinovea software and the values were analyzed using the software MS Excel and in stat.

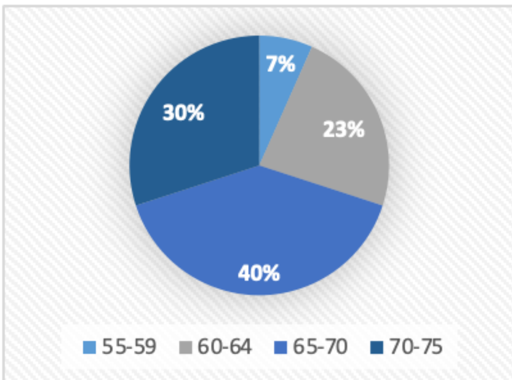


**Figure 1.** Percentage of age of participants

## RESULTS

**Table 1.** Demographic data

| | Total Number | Mean±SD |
|---|---|---|
| **Age(Years)** | 30 | 67.13±5.07 |
| **BMI (kg/m2)** | 30 | 29.83±4.06 |

Interpretation- Cadence was measured and it was observed that 5 subjects had a cadence below the considered normal range (90 steps/min) (p<0.0001, Table 2).

| Cadence (steps/min) | Count of Patient |
|---|---|
| 70-74 | 1 |
| 75-79 | 0 |
| 80-84 | 1 |
| 85-89 | 3 |
| 90-94 | 11 |
| 95-99 | 8 |
| 100-104 | 6 |
| **Grand Total** | **30** |

**Table 2.** Cadence

Interpretation- Speed was measured using the kinovea software. It was observed that 6 subjects had a considerable decrease in the speed i.e., < 0.80 m/s (p<0.0001, Table 3).

**Table 3.** Speed

| Speed (m/s) | Count of Patient |
|---|---|
| <0.65 | 0 |
| 0.66-0.70 | 2 |
| 0.71-0.75 | 1 |
| 0.76-0.80 | 3 |
| 0.81-0.85 | 2 |
| 0.86-0.90 | 9 |
| 0.91-0.95 | 6 |
| >0.95 | 7 |

**Table 4.** Step length

| Step Length (cm) | Count of Patient |
|---|---|
| <30 | 0 |
| 31 | 1 |
| 32 | 0 |
| 33 | 1 |
| 34 | 2 |
| 35 | 1 |
| 36 | 2 |
| 37 | 2 |
| 38 | 2 |
| 39 | 3 |
| 40 | 5 |
| 41 | 3 |
| >41 | 7 |
| **Grand Total** | **30** |

Interpretation- Step length was assessed using the kinovea software. The unit of measurement was centimeter (cm). It was observed that total 4 subjects that is 1 subject with 31 cm step length, 1 with 33 cm step length, and 2 subjects were with 34 cm step length had a considerable decrease in step length. As 35 cm is considered normal step length (p<0.0001, Table 4).

**Table 5.** Step width

| Step Width (cm) | Count of Patient |
|---|---|
| <4 | 0 |
| 4 | 0 |
| 5 | 0 |
| 6 | 0 |
| 7 | 5 |
| 8 | 10 |
| 9 | 9 |
| >10 | 6 |
| **Grand Total** | **30** |

Interpretation-Step width was measured while recording the video, the subjects' sole was dipped in water and then the patient was asked to walk. The foot marks left behind on the ground were used to measure the step width. It was observed that none of the subjects had a considerable decline in the step width i.e., <7cm (p<0.0001, Table 5).

**Table 6.** Stride length

| Stride length (cm) | Count of Patient |
|---|---|
| <65 | 0 |
| 67 | 1 |
| 68 | 1 |
| 69 | 1 |
| 70 | 2 |
| 71 | 1 |
| 72 | 1 |
| 73 | 0 |
| 74 | 2 |
| 75 | 1 |
| 76 | 1 |
| 77 | 4 |
| 78 | 3 |
| 79 | 5 |
| >80 | 7 |
| **Grand Total** | **30** |

Interpretation-Stride length was measured using the software kinovea. This was done by pausing the recorded video and then using the tools in the software to measure the distance between the heel of one foot and the heel of the other foot. It was observed that 5 subjects had an altered stride length i.e., less than 70 cm. (p<0.0001, Table 6).

Interpretation-Knee flexion angle in swing phase of gait cycle was assessed using the software kinovea. The recorded video was paused with the subjects' knee in early swing phase and using a tool in the software the angle formed at the knee joint was measured. It was seen that majority Interpretation-It was observed that 5 subjects had a decline in their cadence. Along with all the subjects with decreased cadence 1 more subject had a drastic decrease in his walking speed. Including few of the subjects with altered cadence and speed, 2 more subjects showed a decrease in step length. Stride length and step width were seen altered in the few of the subjects who had alterations in their cadence, speed and/or step length. Along with these 8 subjects, 3 more subjects had a decreased knee flexion angle in early swing phase of gait cycle (Figure 2, Table 7).

**Table 7.** Knee flexion angle in early swing phase

| Knee flexion angle in early swing phase | Count of Patient |
|---|---|
| <40 | 0 |
| 40-45 | 1 |
| 46-50 | 2 |
| 51-55 | 6 |
| 56-60 | 14 |
| >60 | 7 |
| **Grand Total** | **30** |

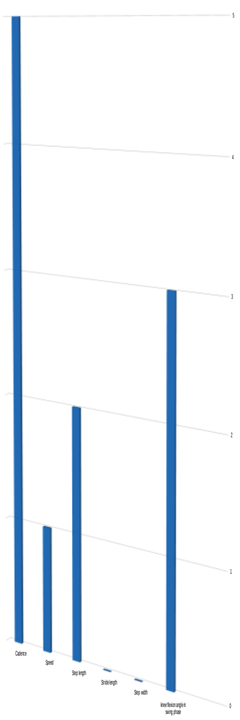


**Figure 1.** Count of subjects with parameters changed

**Table 8.** Count of subjects with parameters changed

| Parameters | Count of Patient |
|---|---|
| Cadence | 5 |
| Speed | 1 |
| Step length | 2 |
| Stride length | 0 |
| Step width | 0 |
| Knee flexion angle in early swing phase | 3 |
| **Grand Total** | **11** |

It can be concluded that 36.67% (11 out of 30) ($p<0.0001$) subjects had some kind of alteration in gait parameters.

**Table 9.** Altered gait parameters

| | Total number | Mean±SD | P values |
|---|---|---|---|
| Cadence | 30 | 94.33± 6.89 | <0.0001 |
| Speed | 30 | 0.88 ±0.08 | <0.0001 |
| Step length | 30 | 39.1± 3.50 | <0.0001 |
| Step width | 30 | 8.1±1.68 | <0.0001 |
| Stride length | 30 | 77.7±6.28 | <0.0001 |
| Knee flexion angle in early swing phase | 30 | 56.76±4.77 | <0.0001 |

## DISCUSSION

This study unfolds a comprehensive investigation into the intricate alterations in gait parameters among individuals who underwent Total Knee Arthroplasty (TKA) at least one year ago. This study aims to provide an in depth understanding of the multifaceted impact of TKA on walking dynamics, exploring aspects such as structural modifications, muscle strength, and functional outcomes.

Structural changes introduced during TKA have a profound influence on various gait parameters. These modifications can manifest as a decrease in the knee flexion angle, subsequently resulting in a reduction in step length. In this study, alterations in step length were observed in four subjects, suggesting a potential compromise in the overall stride during walking. Reduced step length contributes to a decrease in stride length, aligning with the changes in both parameters. This intricate relationship between structural modifications and their consequences on gait parameters is consistent with existing literature, indicating the persistence of altered gait parameters even after the initial postoperative period (Bączkowicz et al., 2018). A comprehensive understanding of these changes necessitates an assessment of the entire gait cycle (Andersson et al., 1981).

The reduction in cadence, contributing to a decline in walking speed, underscores the complex interplay between various gait parameters (McClelland, 2007). The research suggests that the walking pattern persists from before surgery, even though there is an early reduction in pain during walking after total knee arthroplasty (Otsuki et al., 1999). This complex relationship between structural changes and gait alterations highlights the multifaceted nature of the impact of TKA on walking dynamics.

Reduced quadriceps and hamstring muscle strength post-TKA significantly contribute to alterations in gait parameters (Schache et al., 2014). The impact extends beyond the operated limb, evidenced by a progressive decrease in strength in the non-operated lower limb (Yoshida et al., 2012). The reduced muscle strength is evident in the quadriceps, knee flexion angle, and a heightened fear of falling. These factors together contribute to a decreased walking speed following total knee arthroplasty (Pua et al., 2017). Also there is risk of tibial component loosening which might contribute to decreased gait speed (Hilding & M.B., 1996) The intricate interplay between alterations in structure and muscle strength underscores the nuanced character of gait changes following total knee arthroplasty (TKA).

Knee flexion angle during the early swing phase serves as a crucial indicator of joint mobility and overall biomechanics during walking. The observed alterations in nine subjects suggest potential limitations in knee joint movement post-TKA. While the procedure aims to restore joint function, variations in the flexion angle indicate persistent challenges in achieving optimal gait mechanics. Stiffer knee during walking increases the risk of contralateral TKA in patients who have undergone unilateral TKA which can be related to increased load on the contralateral knee hence it is important to have normal gait and symmetrical weight bearing post TKA which further increases the need for continuation of physiotherapy visits after the typical rehabilitation is over. (Ritter et al., 1994).

Despite the initial correction of static knee alignment and a decrease in the peak varus angle during gait six months post-TKA, these improvements tend to diminish over time. A correlation between the dynamic varus angle increase and adduction moment elevation from 6 months to 1 year suggests evolving biomechanical challenges (Orishimo et al., 2012). Biomechanical alterations in the knee and ankle were detected after total knee arthroplasty (Levinger et al,. 2013). Improving knee biomechanics is important as its associated with improved quality of life in post TKA patients (Naili et al., 2017). Even one year after undergoing surgery, a significant number of TKA patients exhibit no enhancement in their walking compared to pre-operative conditions (Rahman et al., 2015). These findings emphasize the need for continued monitoring of gait parameters to guide post-operative rehabilitation and formulate effective approaches to enhance mobility in these individuals.

Speed, an essential component of gait analysis, demonstrated a significant decrease in six subjects. A slower walking speed may impact daily activities and compromise functional independence, emphasizing the need for targeted interventions to address this decline. While showcasing improvement, those who experienced total knee arthroplasty (TKA) still displayed a reduced walking pace in comparison to the control group. The diminished gait speed observed after bilateral TKA was associated with suboptimal improvements in knee biomechanics. To boost walking speed, it is advised to integrate exercises that strengthen the quadriceps and aim for an expanded range of motion during walking (Ro et al,. 2017). Participating in physical activity improves walking performance for individuals who have had total knee arthroplasty (Taniguchi et al,. 2016). These findings support the study by (Bonnefoy-Mazure et al. 2017), where improvements in walking speed were observed one year post-surgery.

This study also recognized the role of pain in influencing gait dynamics. It was observed that some patients experience some degree of pain following TKA. The observed pain-related gait alterations manifest as a rigid knee gait, valgus alignment during walking, and TKA components slightly internally rotated (Planckaert et al., 2018). These factors contribute to elevated patellofemoral forces, potentially explaining unexplained pain. Understanding the degree of pain-related gait alterations is crucial for tailoring interventions that address both pain management and gait improvement in the post-TKA period. Greater comorbidity and the existence of pain in other joints in the lower extremities or spine consistently negatively affected the numerical outcomes obtained for gait parameters (Kramers-de Quervain, et. al., 2012).

This integrated analysis of gait parameters demonstrated that 36.67% of subjects experienced alterations following TKA. This highlights the importance of comprehensive rehabilitation strategies that go beyond pain relief and structural corrections, emphasizing the optimization of gait dynamics. Also it was seen that patients are reluctant to adhere to rehabilitation exercises beyond the typical physiotherapy period, particularly in the second year post-surgery. This reluctance poses challenges for sustaining long-term rehabilitation efforts and may contribute to lasting difficulties observed six months post-TKA, as noted by (Bade et al. 2010). Consequently, it is crucial to develop strategies that enhance patient adherence to rehabilitation exercises and encourage long-term engagement with rehabilitation protocols.

***Conclusion***

In conclusion, this study provides essential insights into the persistent impact of TKA on gait parameters, shedding light on the complex interplay between structural changes, muscle strength, and functional outcomes. The observed alterations highlight the importance of tailored rehabilitation programs that extend beyond the typical physiotherapy period, emphasizing the need for sustained efforts in maintaining optimal gait mechanics.

Future research in the field should focus on interventions that promote long-term patient adherence to rehabilitation exercises, strategies for minimizing pain-related gait alterations, and approaches for optimizing biomechanics to improve overall quality of life in individuals post-TKA. This attempt can pave the way for more personalized and effective therapeutic strategies, ensuring that TKA patients achieve not only joint restoration but also long-term functional recovery comparable to individuals without knee issues. As the field progresses, continued exploration of the interplay between structural changes, muscle strength, and gait alterations will undoubtedly contribute to the refinement of rehabilitation strategies, promoting an integral approach to post-TKA care. The integration of emerging technologies, such as wearable sensors and advanced imaging techniques, may offer new approaches for assessing and addressing gait parameters in a more nuanced and personalized manner.

Moreover, an exploration of psychosocial factors influencing adherence to rehabilitation exercises and long-term engagement with rehabilitation protocols is needed. Understanding the patient's perspective, motivations, and potential barriers to adherence can help in the development of targeted interventions that match with individual needs and preferences. Collaborative efforts between healthcare professionals, researchers, and patients can contribute to the co-creation of rehabilitation programs that are not only evidence-based but also patient-centered, encouraging a sense of ownership and empowerment in the recovery journey.

Additionally, a longstanding perspective in studying post-TKA gait alterations could provide valuable insights into the course of changes over an extended period. Long-term follow-up assessments, spanning several years post-surgery, would enable the identification of trends, potential fluctuations, and the durability of interventions. This extended timeframe would also facilitate the exploration of age-related factors, comorbidities, and lifestyle influences that may intersect with post-TKA gait dynamics.

In the area of biomechanics, advancements in technology continue to offer exciting possibilities for refining gait analysis methodologies. Integration with artificial intelligence and machine learning algorithms may enhance the interpretation of complex gait patterns, allowing for more specific and individualized insights. The combination of biomechanical assessments with other modalities, such as neuroimaging or genetic profiling, could open new avenues for understanding the underlying mechanisms shaping post-TKA gait alterations Moreover, collaborative efforts across institutions and international research networks can facilitate the merging of data from diverse populations. A broader and more diverse dataset would enhance the generalizability of findings and contribute to a more particular understanding of the factors influencing post-TKA gait dynamics across different demographics, cultural contexts, and healthcare systems.

In conclusion, this study serves as a stepping stone in understanding the complexities of post-TKA gait alterations. As we travel across this evolving scenario , embracing a multidimensional and patient-centered approach is essential. By addressing the multifaceted nature of post-TKA gait alterations and continuously refining our understanding through ongoing research, we can step forward to optimizing rehabilitation strategies, promoting enhanced functional outcomes, and ultimately improving the overall quality of life for individuals post-TKA.

***Acknowledgment***

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***Conflict of İnterest***

Authors declare no conflict of interest.

***Ethics Statement***

The interventional study was accepted by Institutional Human Ethics Committee of Krishna Institute of Medical Sciences, "Deemed to be University," Karad (Protocol number-617/2022-23).

***Author Contributions***

Study Design, SBK and HAJ; Data Collection, HAJ; Statistical Analysis, HAJ; Data Interpretation, HAJ and SBK; Manuscript Preparation, SBK and HAJ; Literature Search, SBK and HAJ. All authors have read and agreed to the published version of the manuscript.

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